The Journal

OF THE

Royal United Service Institution.

VOL. VI. 1862. No. XXIII.

LECTURES.

Friday, February 14th, 1862.

Captain E. G. FISHBOURNE, R.N., C.B. in the Chair.

IRON AND STEEL AS MATERIALS FOR RIFLED CANNON.

By JOHN ANDERSON, ESQ., Assistant Superintendent Royal Gun Factories, Woolwich.

IF the value of a material were to be estimated by the place which it occupies in the world, in regard to its usefulness for serving the multifarious purposes of mankind, then to the class of metals known as iron and steel in their many modifications must be ascribed an importance and position superior to any of the other mineral substances which have been placed at our disposal.

Iron, including steel, is the great staple article of Britain, and is the chief agent by means of which this country has been enabled to maintain the prominence she holds among the other nations.

In this country alone above five million tons are produced annually; and the increasing applications of those materials, which we daily see going on around us in every branch of the arts of peace, as also their extensive usefulness in connection with the art of war, render it highly necessary that every intelligent individual should have some acquaintance with the leading peculiarities of those substances; and the object of the present lecture is —

1st. To point out generally the nature and the leading characteristics of those materials; and

2nd. To consider their comparative fitness for one of the purposes to which they are applied as munitions of war, namely, rifled cannon.

As there is no other subject in connection with the wide range of practical mechanism engaging more attention at the present time than the one now under consideration, and which is already so well known in many of its details, it cannot be expected that much additional light will be thrown upon it in the present instance, or that any claim for originality can now be made; still it is to be hoped that the first part of the lecture may be useful to some, and that the facts which have come out under my own observation and experiments, which are referred to in the latter part, may be instructive to all.

Although iron is frequently referred to in the Old Testament Scriptures, yet we cannot find that it was extensively used until a much later period; the hindrance to its introduction probably arising from the extreme difficulty experienced in separating it from the earthy matters with which it is found in the condition of "iron ore."

The ores of iron are found extensively scattered all over the world, yet, comparatively speaking, few are now considered as fitted for the purposes of the iron-maker; questions of quality, means of effecting reduction, and other commercial questions, chiefly determine their value.

In Sweden and in some other countries iron ore is found in solid rocks, forming veins in the granite of enormous thickness, such ore being comparatively pure. This ore is supposed to be of volcanic origin, and, being generally in conjunction with igneous rocks, it in all probability at some remote period was belched out from the molten matter within the globe.

But in this country most of our iron is found mixed up with indurated clay or mud, in lumps or nodules; and it is supposed that these lumps are the mud of such veins of volcanic iron ore ground down by the geological floods of an early era.

These lumps are generally found in beds, and frequently just above and under and alternating with the seams of coal by means of which they are to be smelted, and also in close proximity to the refractory material called fire-clay, which is so valuable an agent in their reduction.

Previous to the smelting process, by which the iron is separated from the earthy matter, it is found necessary to subject the ore to a preliminary process of calcining, or, as it is commonly termed, roasting, which is simply a subjecting of the ore to a continuous dull red-heat for a considerable period in order to drive off the foreign matters which are injurious to the quality of the iron, and also to produce a greater degree of oxidation, as well as to open up the ore and render the smelting process more easily effected.

The degree of heat employed in roasting, the period of time required, and the description of kiln or oven which is used, depend entirely on the nature of the particular ore, and are found to differ in almost every locality: in all the object is the same, namely, to keep the ore at such a temperature and for such a length of time as will be sufficient to expel the injurious gases; those conditions of procedure in the great majority of cases being derived from experience rather than from any chemical knowledge of the changes to be effected.

Up to this stage the ore has but little resemblance to the valuable metal which it contains, and the first great step in advance is to eliminate the earthy matter and set the iron free.

This is effected in different ways; but the general method is to put the ore and fuel into the furnace together, then to generate an intense heat by means of a strong blast of wind, until the refractory ore is overcome and the iron begins to melt.

Without some other agent to assist, the process of separation would be very imperfectly accomplished: it is found necessary to employ what is termed a flux. This flux material is also thrown into the furnace along with the ore and fuel, and the chief object of the flux is to unite with the earthy matter and set free the iron.

With argillaceous or clay ore a calcareous flux, generally limestone, is

used; with a calcareous ore an argillaceous flux is employed, or, what is better, a mixture of both descriptions of ore in due proportion.

Under the high temperature within the furnace, the two earthy substances assimilate and form the glassy slag or scoria, which, being lighter, floats upon the liquid iron at the lower part of the furnace, and runs off by an opening left on purpose; while the iron (when a sufficient quantity is collected) is run out upon the floor into the pig-iron of commerce.

From the circumstance that the melting iron is in such intimate contact with the fuel, and from having to pass through it like water through a filter, the quality of the iron is necessarily much affected by the nature of the fuel, and as it so happens that the presence of sulphur, phosphorus, and other impurities is found to affect the conditions of strength and other properties of the iron, those descriptions of iron that are made with the purest mineral fuel are the best, supposing other conditions to be the same, and best of all is the iron smelted with the charcoal from wood, which is obviously more free from those injurious properties that belong, more or less, to all mineral fuel used in the iron manufacture on a large scale, with which I am acquainted.

By subjecting mineral coal to the process of coking, it is purified to a considerable extent, still the iron which is made even with coke is not of such high quality as that made with the still purer fuel of wood charcoal.

It will thus be seen that at the very threshold of the manufacture there are causes in operation that seriously affect both the quality and the cost; and that, although in the manufacture of ordnance, a material of the very best description is the desideratum, still in the wide range of the arts there is, at the same time, a demand for every quality. It thus happens, and that to a great extent, that price rather than excellence is the predominating influence that determines the manufacture.

Iron may be divided into three great classes; these are known as cast and wrought iron and steel; indeed, for all practical purposes, they may be looked upon as three distinct metals.

Cast iron is the material as it runs from the first process of the smelting furnace, and is that from which both wrought iron and steel are made.

During the smelting process, the iron has absorbed a considerable quantity of carbon, as well as still retaining several other ingredients and original impurities, the presence of which renders cast iron capable of being melted and remelted a number of times, and used for the various purposes of the iron-founder, and the metal is sufficiently liquid to admit of being poured into moulds of any form with the greatest facility; hence, if cast iron had the toughness or strength, and the other good qualities of either of the other modifications of this metal, namely, wrought iron or steel, it would necessarily have the preference, not only on account of its cheapness, but also from the great readiness with which it can be poured into almost any variety of intricate outline, at a small expenditure of fuel, wages, or plant.

Cast iron, when considered as a material for the iron-founder of general articles, is mostly affected by the proportion of carbon which is present.

The carbon renders the iron more liquid when in the fluid state, and softer when in the solid condition, at the same time it is not quite so strong in regard to its tenacity, although possessed of more toughness

than iron containing a less quantity of carbon; hence the founder is to a great extent guided in the selection of pig-iron for particular articles by the quality of the compound.

For castings where great strength is aimed at, considerable judgment is necessary in the selection of a mixture that will secure all the conditions of softness or hardness, closeness of the grain, and that degree of toughness and strength, which may be necessary.

There are many instances on record of cast iron having shown an amazing amount of strength, toughness, and general endurance, both as guns and in other constructions; still, at the best, it is uncertain, and, as will be seen hereafter, it is not strong, and is proverbially treacherous to depend upon, as it gives no warning before rupture; and hence the time has arrived when, for ordnance especially, it seems about to give place to a better material, either wrought iron or steel, or perhaps a combination of both.

The malleable, ductile, tough, and fibrous material termed wrought iron, which is so extensively used by the smith for every branch of art, is made directly from cast iron by an elimination from that compound of its carbon, sulphur, silicium, phosphorus, and other impurities, by a process of oxidation.

This purification of cast iron produces a material with entirely different characteristics; it becomes much stronger, has greater toughness, is highly infusible; it loses the property of becoming liquid, and is therefore unfitted for the founder's purposes. At the same time, however, it acquires another property, almost equally valuable, for, when brought to a high temperature, it acquires a viscous or sticky character, so that if different pieces in this condition are brought together, they adhere, and if a blow is given or pressure applied, the separate pieces are made to adhere permanently.

This remarkable property is termed welding, and is the basis of the art of forging, as practised by the smith.

The conversion of cast into wrought iron is effected in different ways, although the same principle is adopted in all, namely, to burn out the silicium and carbon.

One arrangement is, to drive off these matters by fusing with charcoal while a hot blast is playing on the liquid mass; but the more usual plan in this country is to subject the liquid to the well-known process of puddling. The cast iron is melted in a furnace in which a hot oxidising flame is brought to bear upon the fluid; by means of iron tools the mass is moved and stirred and turned over in every direction so as to expose every portion of the iron, in turn, to the influence of the flame.

Under this influence it gradually loses its fluidity, and acquires the viscous or sticky property. It is then parted into lumps of a size suitable for manipulation; each lump is afterwards subjected to a still further process of purification, and one which is dependent on another principle for its efficiency.

The lump of viscous iron may now be compared to a very dirty sponge that requires to be several times wetted and wrung in order to make it pure and clean.

On its removal from the puddling furnace this lump of viscous iron matter, like a dirty sponge, is put under a heavy hammer or other

apparatus, the blows or squeezing of which drive off the impurities, and the mass is worked out still further by means of rolls into a long bar of coarse and dirty iron, unfit for the smith, and which is afterwards cut into short pieces. These pieces are piled up into a bundle, and are again put into a furnace and subjected to another heating; the iron is again brought to the welding state for another washing, and is again subjected to another beating from the steam hammer, and a squeezing from the rolls, all which still further improve the purity and the quality of the iron bar.

For the production of the better descriptions of iron, this process of purification, of cutting up, re-welding, and hammering or rolling, is repeated several times until the proper quality is attained. Of course such treatment, while it improves the material, also increases the cost in a still greater proportion.

Even after the best treatment, the wrought iron of commerce is not chemically pure, although its combination with the grosser impurities does not seem to be of that intimate character that exists in cast iron. It still contains carbon, silicium, and other matters, which fill up the minute vacant spaces between the fibres which compose the structure of the bar.

In consequence of the great affinity which iron has for sulphur, phosphorus, and other impurities that affect its quality, the quality of wrought iron is much dependent on the character of the fuel employed in its manufacture; the purer the coal the better is the iron, and hence that which is made with wood-charcoal is necessarily the purest and best, although, at the same time, it is most expensive.

The quality of wrought iron is also greatly dependent on the original selection of the mixtures of cast iron for puddling, and on the care, skill, and close attention which are brought to bear upon all its successive stages; hence iron comes to differ as much in its qualities and properties as any two materials of the same class could be expected to be capable of doing, and more so than that of any other similar substances with which I am acquainted.

This difference, however, is only detected when high conditions are aimed at, then close observation discloses innumerable shades of quality, that escape the observation of the majority of workers in iron, who use the material for purposes where the object required is easily secured.

The conversion of cast into wrought iron by the removal of carbon and silicium completely changes the characteristics of the material. It has lost the brittle property; it now yields and stretches before it breaks; the permanent yielding point is now higher than the former breaking point, and the breaking point is double that of the yielding point.

These are all strong conditions in its favour, but at the same time it has many serious defects.

It is difficult to produce in large masses that are perfectly sound throughout; the smith or forgeman has little control or authority over its behaviour when in the welding furnace, and hence it is extremely difficult to produce large forgings perfectly sound, even with the best treatment; there is, therefore, still great room for improvement, so as to ensure a perfectly homogeneous mass, possessing all the good properties of the malleable, welding, tough material, and which, at the same time, shall be free from its numerous defects, veins, and unsoundness; yet it is but just to

add, that, with all its many defects, there is no material at the present time which can be so implicitly relied upon and trusted with so much security against fracture from sudden vibration, as a piece of good sound wrought iron.

The material called steel is an intermediate compound between cast iron and the former material of wrought iron.

Steel is comparatively a pure iron, containing a small per-centage of carbon with some other substance in combination, which is rather obscure, and regarding which there is considerable difference of opinion. This combination gives the material some very peculiar characteristics of its own, and is entirely different in character from either of the metals out of which it is made.

Steel can either be made from wrought iron or from cast iron.

The latter arrangement is the cheapest process, but the former method affords the most certain results at the present time, and that is the system chiefly resorted to in making the finer qualities of steel.

To make good steel of high quality, a bar of pure wrought iron is selected, mostly Swedish, which has been made with charcoal in all its previous stages. The iron bars are put into a fire-brick chest, along with a quantity of charcoal powder; every part of the bar being surrounded with the carbon, the air being excluded, the whole is made white-hot, and kept in that condition for several days, generally about a week, according to the amount of conversion that is required. During this period the pure white-hot iron imbibes a new property from the charcoal into its own nature.

A chemical action takes place, and the wrought iron has been thus gradually turned into steel. Such steel, however, is very imperfect. The defects are chiefly owing to its local irregularities of conversion, for although the entire mass of the bar may have had the proper quantity of carbon put into it, yet it is found to be much improved through mixing the particles, either by welding several bars together into one bar, or even the mere working of a single bar under the hammer has the effect of equalizing and greatly improving the quality.

The most effectual way, however, of obtaining a thorough mixture of the particles is to break the original steel bars into small pieces, then to melt them together in a crucible into liquid steel, and then to mix and pour this metal into an ingot, which, when solid, is then drawn into a bar of steel of the required dimensions.

By this means of putting carbon into pure iron, cast steel is produced, which is the finest in quality of any of the varieties of this valuable metal. But good passable steel can be made directly from cast iron, simply by not carrying the puddling process on to the full extent of wrought iron. Such material is called puddled steel; and although at the present time it is not equal in quality to that which is made in the other way, still it is very much cheaper, and when more experience has been gained so as to determine the best descriptions of cast iron that are suitable for this particular process, as also the precise period when to discontinue the puddling operation, so as to leave the proper quantity of carbon in the metal, there can be no doubt but that such cheap steel will be extremely valuable for many purposes, seeing that puddled steel is malleable, and has even a higher tenacity than wrought iron.

A very fine material is now produced extensively by breaking up the

rough bars of puddled steel and melting them into a cast steel, and which for many purposes is found equal to ordinary cast steel as made from Swedish iron; so far as I am aware, however, it is not so good for edge tools.

Good steel can be made in a still more summary manner by means of the "Bessemer process." The crude cast iron, when in a melted state, is poured into a large refractory vessel previously heated, and a strong blast of air is forced through the fluid, producing a violent agitation.

The silicium and carbon in the iron unite with the oxygen in the air, and are driven off from the metal, until the remaining mass is almost pure wrought iron.

There is then added to the iron (in order to make it steel) a definite quantity of carbon; it is introduced in the condition of liquid cast-iron, of known mixture and quality; the whole is then thoroughly mixed, and the entire process is completed in about half an hour from the time of first pouring in the cast iron to the final running out of the steel into moulds or ingots.

By the Bessemer process large masses of steel can be made more easily than by any other method yet introduced, and apparently at less cost, and there is no doubt that in time this process will produce uniform quality.

Steel in all its combinations is a most valuable metal; in its ordinary state it is closer in structure, has greater power of resisting compression, and possesses a higher tenacity than wrought iron, even of the best quality, and as such it commends itself to the engineer for the manufacture of the best class of articles, notwithstanding its greater cost, and the still greater expense which has to be incurred in its fabrication into the requisite forms. But it has another property, which causes it to transcend in value all other metals, namely, the capability of being tempered to any degree of hardness or softness.

The discovery of the fact that a piece of soft steel, when heated, and then suddenly cooled, no matter by what means, assumes a hardness approaching that of the diamond, is perhaps the most important of any in connexion with the whole range of metals, and has been of the greatest service to mankind.

In addition to this property of hardening, when the said hard substance is exposed to a gentle heat, it gradually begins to give up a portion of its hardness, until at length it loses it altogether; and as it so happens that at the same time that the hardness is gradually departing, a definite change of colour of the surface of the steel accompanies the softening process, this change of hue becomes a correct measure of the change in hardness, and thus the precise degree of hardness or temper that may be required for any purpose can be attained with great certainty and uniformity.

Steel, wrought iron, and cast iron can all be rendered softer and less brittle by means of the annealing process, which is simply causing the materials to be made red hot, then keeping them in that state for a short time, and afterwards allowing the whole to cool down very slowly, so that every part may cool at a uniform rate, and no part or particle be under any restraint from premature withdrawal of heat, thus causing local contraction and hardness.

By prolonging the period of cooling, a mass of steel comparatively

brittle acquires the character of toughness in a remarkable degree, and this process of annealing now plays an important part in all modern efforts to use steel either for guns or armour plates, or for anything exposed to jar or sudden vibration.

Such is a brief description of the metals—cast iron, wrought iron, and steel—which are now attracting so much attention in the world, more especially in regard to their adaptation and application as materials for war purposes, and which are now to be shortly considered in regard to their several and relative fitness for the manufacture of rifled cannon of large calibre.

The numerous and repeated failures that have occurred, and are still occurring, in the application of iron and steel for the above purpose during the past few years, and even at the present time, clearly show, that that which is wanted, necessarily implies some high conditions which are very difficult to secure, and which appear all the more difficult to those who are the most concerned, and whose province it is to endeavour to obtain them.

For small arms, and even for cannon of the smaller class, there is not much trouble experienced in applying almost any good material, whether bronze, iron, or steel; but in dealing with heavy breech-loading guns of large calibre, elements of weakness are brought into view which are exceedingly difficult to provide for and meet successfully.

The severe proof to which rifled guns are now subjected, consisting of seven rounds, with two of the charges of gunpowder being equal to one quarter of the weight of the projectile, is found to thoroughly search and try their soundness, both in regard to the materials and the workmanship, and is sure to develope any seriously defective part, if such exists; but the mere withstanding of the proof rounds is found not even sufficient to thoroughly test the perfect soundness of a gun.

In wrought-iron guns, which have resisted proof successfully, minor defects will sometimes appear after a number of ordinary service rounds; such defects have required a repetition of charges to bring them out into view for examination, each successive round acting like the blow of an enormous sledge-hammer, and gradually producing an alteration of form in the bore or in other parts of the structure.

Again, there are some of the steel class of materials that have been tried, apparently with great success, which have not only stood proof, but have been fired a great number of times, and yet prematurely have been ruptured; the effect of the firing seems to derange the crystallization, and to have been like the repeated blows of the hammer driving home the wedge, until a separation of the particles is effected.

It is also found, however paradoxical it may appear, that the strongest material after a certain point, whether of wrought iron or steel, makes the weakest gun; that wrought iron as it approaches the character of steel, while becoming better adapted in several respects, is getting all the worse in other respects still more important; and that when steel is annealed and otherwise treated, until it seems to be losing all the good qualities for which it is so celebrated, that then it is becoming all the better adapted for the sudden jar and vibration of a gun, but at the same time it is losing some of those good qualities which chiefly recommend it as a competitor with wrought iron for the construction of rifled cannon.

So far as my present experience goes, we are still in want of the proper, the perfect material for the interior of the bores of large guns, a material that will afford bores invariably sound and perfect, and which will remain so in the same manner as an ordinary musket barrel, and which at the same time shall be as safe against bursting, as guns built up of wrought iron on Sir William Armstrong's principle, which in that respect may be considered perfect, and as fulfilling all that is or can be desired or reasonably expected.

The extraordinary effect that is sometimes produced in the bores of rifled guns made of any description of metal which will not be in danger of bursting, from its hardness, is much greater than is generally supposed, and is only known to those who are more immediately concerned, ordinary bronze gun-metal being acted upon in the manner that lead would be, only in a less degree. The shot or shell in such rifled guns requiring considerably more power to set it in motion as compared with the round ball from a smooth bore—the abrupt check of the wave of gas suddenly arrested in its progress—the amount of work to be done in whirling the projectile up to such a velocity in so short a space of time—the lengthened period during which the pressure exists in the rifled gun—as also the extremely violent action of the highly worked gunpowder which is used in England,—all these causes combine to render the effect of the powder upon the interior of large rifled guns very considerable, and involve a high standard of quality in the materials employed.

Before considering the fitness of any particular metal for the manufacture of rifled guns, let us enumerate some of the properties which are absolutely requisite to insure perfection.

The desideratum, then, for the interior and general structure of rifled guns is a material which should possess all the following characteristics:—

1st. That it shall be capable of withstanding the violent action of the most active gunpowder against rifled projectiles without producing the risk of fracture or even inordinate deterioration in the bore, and that it shall not be in danger of bursting at any future time by the effect of continual firing causing deterioration of the quality of the metal.

2nd. That the material to be employed shall have sufficiently high tenacity and general strength as will not render necessary the employment of a greater weight of gun than what is considered reqnisite by the artillerist to absorb the recoil.

3rd. That the material shall be sufficiently hard, so that the surface of the interior of the bore shall not in any way be indented or bruised, or otherwise acted upon, by the powder or projectile, or even by the premature fracture or explosion of a cast-iron shell within the bore.

4th. That the material shall be such, as that guns can be easily manufactured without much risk of radical defects, and that the guns, when properly made and proved, may with confidence be considered right in all respects, and without any doubt or uncertainty as to their positive soundness or future stability when in actual service.

5th. That the guns when made shall not be too costly.

Having already hinted that none of the existing metals, whether cast iron, wrought iron, steel, or even bronze, so far as I am aware, fulfil their function in all these conditions, still, having no other available source but

these, especially iron or steel, to fall back upon, let us consider some of their respective properties, and appreciate their fitness in proportion to their several merits; that being the best which promises these several conditions in the highest degree, and in the order of their greatest importance to the soldier in the hour of battle.

In order to be able to arrive at a correct comparison of the several metals, it is not only necessary to know definitely their respective resistance to compression and extension, but we also want to know with equal certainty their relative toughness, elasticity, and general behaviour, when exposed to strain combined with extreme vibration.

In regard to these two latter properties, little has yet been done to reduce them to the actual test of definite experiment, hence we can only infer from the general facts shown by the behaviour of the guns constructed of the several materials, and, as a rule, this is a very safe guide, providing there is sufficient experience on which to guide the judgment.

With regard to the strength of the several materials, especially their resistance to compression and extension, there are abundant data and full opportunity of obtaining positive knowledge so far; from which, however, if the other properties of toughness and elasticity are not considered, we are apt to draw a very unsafe conclusion.

With reference to the first of these properties, namely, compressibility, it is remarkable that the resistance to compression in each of the three materials referred to is more nearly equal than any of their other properties.

The pressure per square inch which is required in either metal to produce a permanent sensible indentation or shortening, about equal to three thousandths of an inch in measurement, ranges from 30,500 lbs. to 40,700 lbs.

This does not refer to the ultimate force which is required to crush the specimens into fragments, because for a gun that is of no consequence, as such an extreme test is not called into requisition. The proper material must be such that there is no sensible compression produced in the vicinity of the bullet-chamber by the force of the explosion or projectile. Hence the measure of strength or fitness is the point where the material begins to set permanently, and, so far, that is the best material which requires the greatest pressure.

Ten specimens of cast iron, parts of guns of the highest quality, but which have been severally burst, gave 35,000 lbs. per square inch; producing an average compression of three thousandths of an inch. The softest being 30,000 lbs., the hardest 40,300 lbs.

Ten specimens of rolled wrought-iron bar, made specially for guns, the specimens being selected at random and reduced from bars three inches square, all of the highest quality and suitable for guns, gave an average of 33,000 lbs. per square inch, with an average compression of three thousandths of an inch. The softest requiring 31,000 lbs., the hardest 35,000 lbs.

Ten specimens of wrought iron, cut from large gun-forgings of superior quality, gave an average of 26,900 lbs.; producing an average compression of three thousandths of an inch. The softest being 22,800 lbs., the hardest 31,000 lbs.

Ten specimens of soft cast steel of the finest quality, and that either withstood the proof-rounds, or which failed before the seven proof-rounds were completed, gave an average of 35,500 lbs. per square inch, with an average compression of three thousandths of an inch. The softest being 25,000 lbs., the hardest 46,000 lbs.

Ten specimens of cast steel, more highly converted than the former, and in quality almost fit for cutting instruments, but which broke first round at proof, gave an average of 76,000 lbs. per square inch, with an average compression of three thousandths of an inch. This kind of steel therefore need not be considered as of any value, however good in other respects, it being totally unfit for guns or armour-plates from its brittleness or want of the necessary toughness to withstand the vibration.

A specimen of cast steel, cut from a gun made by Mr. Krupp, of Essen, but from a gun which failed at proof, gave 25,300 lbs. per square inch, with a compression of three thousandths of an inch.

Four specimens of steel and iron, welded together like layers of sandwiches, gave in the direction of the fibre, that is, pressing the steel and iron upon the edge of the sandwich, an average of 26,000 lbs per square inch, with an average compression of three thousandths of an inch.

Four specimens upon the flat of the sandwich, thus pressing the two metals closer together, gave an average of 25,400 lbs. per square inch, with an average compression of three thousandths of an inch.

It will thus be seen, according to these experiments, which were all made on carefully prepared specimens, exactly one inch in length and half an inch in diameter, that the average resistance to three thousandths of an inch compression, or shortening, was as follows :—

	lbs.
1. Cast steel - - - - - - -	35,500
2. Cast iron - - - - - - -	35,000
3. Wrought-iron bar - - - - - -	33,000
4. Wrought-iron forgings - - - - -	26,900
5. Sandwich steel and iron on edge - - - -	26,000
6. Sandwich steel and iron on flat - - - -	25,400
7. Krupp's cast steel - - - - - -	25,300

The chief point to be observed in regard to the compression of cast steel, which is the highest on the list, namely, 35,500 lbs., is the wide range from the softest to the hardest, from 25,000 lbs. to 46,000 lbs.; this characteristic of want of uniformity is found to be its prevailing feature and failing, and is the case with all the steels, even from the best houses which have come under my examination; and from the nature of its manufacture it is perhaps impossible to make steel positively uniform.

But if it could be made uniform, and if to the harder steels could be superadded the property of toughness so as to keep together, and if at the same time the brittleness could be withdrawn so as to give it the opportunity of recovering from vibration, it would then be invaluable both for guns and armour-plates; but so long as the cast-steel manufacture is uncertain in its produce, no matter how good it may be occasionally, the gun-maker will look upon it with suspicion, as a single failure produces so much mistrust.

The second on the list is cast iron, which is also very high, 35,000 lbs., and so far is good, but, like steel, it has also a wide range, from 30,000 lbs. to 40,300 lbs. If this metal had tenacity and toughness in proportion to its incompressibility it would, from its cheapness, have the decided preference; but so long as England is aiming at high results in her gunnery, the want of those properties will prove a strong objection to its adoption for rifled guns, unless cast iron can be much improved in tenacity and made more certain in its general character.

The third on the list is wrought-iron bar at 33,000 lbs., with the small range of from 31,000 lbs. to 35,000 lbs.; and this is the peculiar feature of wrought iron, it is never high nor never low; on the contrary, wrought iron from any particular maker, who is careful in the manufacture, is found to be nearly uniform, and, being possessed of great toughness and being without brittleness, it is exceedingly reliable so far as its strength will permit.

The fourth is that of wrought-iron forgings, which is considerably under bar iron, 26,900 lbs., also with a wider range than bar, and hence the less valuable so far—from 22,800 lbs. to 31,000 lbs.; the hardness and softness of large forgings being so much affected by the locality of the blows upon the mass.

The fifth and sixth upon the list are the Sandwich specimens, which are not of so much importance, except that as combinations they have been found to stand in some applications where steel failed from brittleness, and where soft iron was found to yield from lateral bulging; and no doubt the low position is partly due to the condition of the iron, and also to the soft quality of the steel which was necessarily used in order to get a good sound welding between the two classes of material, the iron and steel.

The softest material on the list is the famous cast steel made by Mr. Krupp of Essen. Only two specimens were operated upon, and gave 25,300 lbs. As will be seen, the hardness of this material is considerably under wrought iron, and, so far, is that much inferior in this respect. This material is so soft as to admit of being flattened down to any extent; indeed, the same remark applies to most of the good qualities of steel which are under 40,000 lbs.; they continually yield more and more by the increase of pressure, and the structure of the steel shows a wonderful adaptation for keeping together without cracking at the edges, unlike almost any of the other descriptions of material. This property is greatly in its favour, both for guns and armour-plates; and if it could be made to resist a sudden shock as well as it does the effect of mere pressure, it would be exceedingly valuable.

It will thus be seen that the several classes of material here referred to do not differ so much in the foregoing respect as might be expected, unless we are to include the extremely hard qualities of steel, which are from their hardness and brittleness obviously unfitted for guns; such qualities of steel rise up to 80,000 lbs., and can only be made available for the purposes in question by a long course of annealing, which is a process that may be continued until the metal is as soft as the lowest specimens which have been referred to; such softness, however, diminishes their value in proportion to its amount.

In regard to the other property, namely, that of tenacity, there is a

much greater difference existing between the cast iron, wrought iron, and steel, and it has also to be observed that they differ still more in their amount of elasticity and capability of stretching before fracture.

Cast iron and hard steel invariably break at the moment of perceptible elongation when the specimens operated upon are in short pieces, while wrought iron and soft steel have a considerable amount of elasticity, and only begin to permanently elongate after a certain load per square inch has been suspended, and they gradually continue to stretch with every increase of load until final rupture takes place.

As the measure of strength of any material wherewith to construct a gun, is the point at which permanent elongation commences, that point should have the chief attention; still it is requisite for comparison to specify the ultimate strength as well, in order to show the margin of strength which lies beyond this point; thus the several metals can be compared in regard to their relative fitness so far as the property of tenacity is concerned.

From several hundred experiments made with the higher qualities of cast iron which were collected with a view to obtain the strongest iron for cast-iron guns, the ultimate tenacity was found to range from 10,886 lbs. up to 31,480 lbs., or an average of 21,173 lbs. per square inch.

This is considerably above the strength of the greater proportion of the cast iron of commerce. The average of the Nova Scotia iron, specimens of which have recently been tested, gave only 15,821 lbs., and some of the Scotch pig-iron selected at random only gave 12,912 lbs.

It will be observed that the foregoing are the ultimate breaking points of cast iron, and gave no stretching or appreciable warning before fracture.

Of late years, and up to the present time, cast iron has generally been used for heavy guns, but its low tenacity and brittle, uncertain character renders it peculiarly unfitted for this purpose, and more especially is it unfit for rifled guns, as in them not only is the strain considerably increased, but the duration of the strain is prolonged in addition, thus producing a rupture before the particles have recovered from the vibration.

It is therefore inferred that, until an element of toughness can be given with certainty to that weak material, it can never be thoroughly depended upon in the construction of the armament of the future, notwithstanding its cheapness and facility of construction.

Although a small piece of cast iron under the testing process gives no warning, yet cast-iron guns which have stood the proof rounds, if closely watched, begin to show the lines of future failure long before the period of ultimate fracture, and the practised observer can generally indicate the probable number of rounds that will elapse before the gun gives way altogether.

At the same time there are several instances on record of cast-iron guns having exhibited an extraordinary amount of endurance, but the toughness is variable and uncertain, and nothing uncertain is to be commended.

From several hundred experiments that have been made with wrought iron cut from bars intended for the manufacture of Armstrong guns, the following result has been obtained.

The point of yielding permanently gives an average resistance of 28,000 lbs. per square inch, while the point of ultimate rupture gives an average of 57,120 lbs., or rather more than double that of the point where

permanent elongation commences; the margin that lies between these two amounts is of great importance as a condition of safety, but the chief point is that where the stretching begins.

After the first yielding by the addition of extra weight, the wrought iron specimen gradually stretches until it has been considerably reduced in diameter; and such parts as have been so reduced have a greater tenacity per square inch than when in the previous normal condition. The iron has to a small extent assumed the character of wire, which from the drawing process is always stronger than the iron out of which the wire is made.

This increase, however, if given to wire, is lost afterwards when the iron or wire is brought to a welding heat, and hence for gun purposes this property cannot readily be taken advantage of.

From ten specimens of wrought iron cut out of heavy forgings, a lower result has been obtained than from bar iron, such forgings being inferior in all respects.

In such masses, from their not having an equal amount of working in proportion to the extent of heating to which they are exposed, the tenacity is not so high as that of the more highly worked rolled iron when it comes direct from the rolls. In forgings, the average point of yielding permanently was 23,760 lbs.—average point of ultimate fracture being 48,160 lbs. The forgings from which the specimens were cut were all of high quality.

When rolled bars of the best quality are wound into coils, and then welded into cylinders for gun manufacture, the iron as a general rule is found to suffer to about 3,481 lbs. per square inch on the average.

The following shows the average results both in regard to yielding and breaking:—

Yielding point.	Iron in bar - - - -	31,100
	„ cylinder - -	27,852
Rupture point.	Iron in bar - - - -	58,986
	„ cylinder - -	55,500

The loss is due to the necessary heating being greater in proportion than the working.

From experiments that have been made to ascertain the tenacity of welds of iron of different qualities, and under different circumstances, it has been found that with iron of the finest quality, when brought to the proper heat in a fire free from impurities in the fuel, and with the joint scarfed so as to increase the area, the strength is equal to that of the solid iron, which is of course all that could be desired, and is in round numbers about 25 tons, or 56,000 lbs. per square inch.

With all other descriptions of weldings which I have yet tested, the result is lower than the above, down even to 12,000 lbs. per square inch, the same care having been observed in every instance.

Two pieces of the best quality of iron butted together, under the best conditions which I have been able to effect up to the present time, have only given an average ultimate tenacity of 32,140 lbs. per square inch, which is only a little over the half of the iron bar.

Iron butt welded to steel under the best conditions invariably breaks at the weld, and shows only an average tenacity of 26,800 lbs.

But even this depends entirely on the nature of the iron and the steel; any increase of hardness or of the steely property, either in the iron or in the steel, affects the strength of the weld in many cases down to 10,000 lbs. and even still lower.

In the construction of the Armstrong guns the bar iron is first wound into a spiral coil, and then a welding heat is taken through the entire mass, and by means of a steam hammer it is welded into a homogeneous cylinder.

With iron of the very best quality which we have as yet been able to obtain, the highest average tenacity of the welding of the coil has been 32,140 lbs. per square inch, the iron being 55,500 lbs.

With other iron also of high quality and of still greater tenacity, the welds have been lower down, even to 10,000 lbs. per inch; hence such iron, however strong, is, from the steely property, unsuitable for being made into coils; the defect being due to the reluctance shown by harder and stronger iron to unite when raised to a temperature that will not otherwise injure the quality of the material, and cause it to blister.

It will thus be seen that the ultimate strength of a coil in the circumferential direction is about 55,500 lbs. per inch, while in that of its length it is only 32,140 lbs. per inch, and when stronger and harder iron is employed it is even much less in the latter direction and the difference is proportionately greater; hence such steely iron must be avoided for purposes where much dependence has to be put on the welding.

In building up guns of cylinders, this high tenacity afforded by the coil system circumferentially, and the opportunity which it gives of knowing the soundness of the gun structure in every part, and from the fact that every part of the gun is put under the full exercise of its duty from the commencement,—this arrangement of building up guns will always have an immense advantage over guns made of a single solid forging in point of strength and security against bursting of the whole structure; and even when the coiled cylinder is considered as a means of obtaining the inner lining or bore of a rifled gun, a purpose for which it is by no means so perfect, yet even in that respect it is superior to the bore which is formed within the heart of an immense forging, of dimensions suitable for a large gun, such a mass of forging being always more or less defective even under the best and most careful workmanship.

This remark does not apply with the same force to the bores of guns when formed from a smaller forging in which the exterior only has been left as a shell or tube; the outside of such a forging, when properly treated, has a tenacity in all directions equal to that of the solid forging, consequently it is not so strong as the coil in the circumferential, at the same time it is considerably stronger in the longitudinal, direction, and is much more free from defects than the heart of a greater mass in larger forgings.

Turning to cast steel, we find that the range of tenacity is extremely wide—from 114,000 lbs. down to 67,000 lbs. per square inch—but it so happens that the higher qualities, judging from Woolwich experience, are altogether unsuited from their brittleness and great tendency to fracture, and, considering that no metal should be taken into account but that which can be depended upon, I shall only refer to qualities that have been successful in resisting the proof rounds. This quality averages about

80,000 lbs., and it is generally found that the weakest are really the strongest, and if the supply of suitable steel could be obtained with unvarying precision in regard to that degree of hardness, tenacity, and toughness, which is sometimes produced, it would be all that could be desired; but, unfortunately, it is fickle, treacherous, and uncertain, and hence for certain parts of the Armstrong gun that were formerly of steel, and for which some of the properties of steel are desirable, wrought iron of fine quality is now substituted, which, so far as not breaking is concerned, answers the purpose most satisfactorily, although not so good as steel in other respects.

The gun supplied by Mr. Krupp, which was formerly referred to, but which failed at proof, gave a tenacity of 72,000 lbs.; judging from the appearance of this metal beforehand, its softness and perfect soundness, I had great expectation of its being all that could be desired, but was disappointed.

Such a mass of homogeneous steel, after having been cast into an ingot, all its impurities floated to the surface, then well worked under the hammer, and afterwards properly annealed, has a degree of perfection in the bore in regard to entire freedom from specks, seams, or flaws, superior to any wrought-iron structure, coiled or forged, and some remarkably fine guns have been constructed with such steel linings, having the main structure of the gun built up with wrought-iron hoops to give the requisite strength to the steel lining. Such a combination gives the perfect bore and the strong gun, but there is not yet sufficient experience to enable me to assert positively, that the steel will not give way under long-continued firing; but the great difficulty lies in the inability of the steel-maker to insure uniformity, for an occasional gun bursting destroys all confidence.

Such are the several metals now used as materials for guns. Cast iron is the cheapest but the least trustworthy. Wrought iron, built of coiled cylinders, will afford the greatest strength, and is the least likely of all to burst by continued firing; and although in the first instance it will cost three times as much as a cast-iron gun, yet, as its endurance is more than ten times greater, judging from recent results, and as it is never likely to burst with any reasonable amount of firing, I consider it the safest investment, even in a money point of view.

The wrought-iron solid-forged gun, when moderately sound, is much superior to the cast-iron gun, but is inferior to the built-up wrought-iron gun; and, considering the chances of defective bores in the large masses of solid forgings, it will be found as expensive as the latter, and not nearly so reliable.

Cast steel is the most expensive of all, yet, from its soundness in the bore, if it could be made as trustworthy as wrought iron, and if at the same time it could be depended upon for the certain possession of toughness, it would be perfection, notwithstanding the cost; but the uncertainty of manufacture which now exists must first be completely removed before it can be compared with wrought iron as an instrument for men to fire and stand alongside with perfect assurance of safety; and, as wrought iron is so reliable and the cost moderate, there is no particular want felt for steel to constitute the entire body of the gun.

What the world requires is a quality of steel that will be perfectly reliable as an interior lining to a wrought-iron built gun; such a com-

bination will secure all the conditions that are wanted to meet the requirements of the artillerist at the present time.

Such steel should be considerably harder than wrought iron, at the least equal to 50,000 lbs. required to produce sensible shortening on a square inch, but at the same time it must be without brittleness and possessed of toughness at least equal to soft wrought iron, entirely free from honeycomb defects throughout, and which can be produced in a manner and by a process so definite, that there will be no change in the supply and no risk run of uncertainty in the quality of a crystalline structure that shall not be rendered brittle by continued firing, but which shall be as permanently safe and hold on, like good sound wrought iron.

These are high conditions not yet reached, so far as I am aware—not that it is not occasionally attained by some of the best steel makers, and hence there is hope to encourage perseverance; but at the present time, even with the greatest care, the precise quality is uncertain; still, by inferring from the progress recently made in the manufacture of iron and steel, and the great advantage which will accrue to those who are successful, we may reasonably expect that, by aiming high and with a well-directed effort, those conditions will ultimately be realized, and the gun-maker, by a judicious combination of a steel bore within a built-up wrought-iron structure, will be enabled to give the soldier a perfect instrument on which he can implicitly rely, and which will last for ages; meanwhile, considering the materials of iron and steel, as we now find them, and after balancing all the several advantages and disadvantages, wrought iron is the most reliable, even if not so perfect in other respects.

Friday, February 21st, 1862.

CAPTAIN E. G. FISHBOURNE, R.N., C.B., in the Chair.

REMARKS on the PROPOSED SPITHEAD FORTS in connection with the ADVANCED SEA-WORKS advocated by Mr. W. A. BROOKS, C.E. for the DEFENCE of PORTSMOUTH and the ADJACENT ANCHORAGE.

By W. A. BROOKS, Esq. Mem. Inst. of C.E.

THE title which I have given to the paper which I have been allowed the honour of bringing before your useful Institution may appear to place me in the position of being fairly charged with presumption, in thus intruding the opinions of a civil engineer on a subject which seems to be essentially one of a purely military character; but the sequel will, I trust, show that it comes within the range of my long experience in works in which the influence of the tidal currents constitutes an important element; and to this department of the question I shall first direct your attention.

In the observations which I shall also have to make when drawing a comparison between the relative powers of defence offered by the isolated circular forts proposed by the Royal Commission on the National Defences, as contrasted with those of the advanced sea-works projected by myself, I must at once admit that the usual duties of the civil engineer are so far foreign to those of the military engineer, that the necessary preliminary study of the subject is usually so entirely absent on the part of the civil engineer, that any interference on his part will rarely fail to cause the old caution of *ne sutor ultra crepidam* to be justly applied to him.

Acting under the guidance, however, of an experienced officer of the Royal Engineers, practical civil engineers and contractors would become most useful auxiliaries; but without that guidance, or without the preliminary study of the principles of fortification, both of field and permanent works, the intrusion of their services would be found to produce injurious results.

While yet a youth I became the possessor of Carnot's popular work, "An Account of the Defence of Fortified Places." Its glowing language warmed me to the subject; and for years I entered with enthusiasm into the studies of the military engineer, and in doing so became the possessor of a large collection of the best works written here, and on the continent, on the subject of fortification, both field and permanent; so that, although now inferior in information to probably the youngest officer of the corps of Royal Engineers, I nevertheless have that confidence in approaching the purely military part of this paper, which nothing but a previous professional study would give.

When, on the 21st of June last year, I had the honour of being allowed to submit to the Royal United Service Institution my plan of Langston Mole, and other sea-works for the improvement and defence of Portsmouth and Langston Harbour, as well as of the Roadstead of Spithead, I treated those works simply as addenda to the isolated forts recommended by the Royal Commission on the National Defences; and in that respect hardly did justice to my own projected works, in so far as the latter would virtually supersede the necessity for carrying into execution two, if not three, at least of the costly forts recommended by the Royal Commission, viz. those on the Horse and Spit Sands, and possibly even of that proposed to be erected on the useful position of the Sturbridge Shoal, in the event of a hostile squadron having been able to force a passage between the more advanced forts.

In the paper which I then read, * I confined my remarks to the effect which the works proposed by myself would have upon the tidal currents in their vicinity, and upon the Roadstead at Spithead and Portsmouth Harbour; but it does not appear that any public notice has hitherto been directed to the question as to the effects which will be produced by the influence of the isolated forts upon the local tidal currents; and to this subject I shall at once endeavour to direct your attention, the forts referred to being described on the chart as the centres of the red circles of radii of 1,000 yards, showing also their supposed effective fire at that distance of 1,000 yards by red radiated lines.

First. In respect to the alterations in the navigable channel into Portsmouth Harbour, which will result from the erection of the fort proposed by the Royal Commission on the Spit Sand, near the Spit Buoy.

This work would produce an injurious effect upon the sailing channel, because it would cause a considerable deposit of sand and shingle in a direction east-south-east of the fort, and would convert into a circuitous course the present straight channel abreast of the Spit Buoy. It would cause two deflections to be made by the current of the ebb out of Portsmouth Sea Reach, both of which would be attended with a diminution of available navigable depth in the channel.

I am fully borne out in this opinion by the records of the set of the current of flood-tide which appear in the "Sailing Instructions into Portsmouth Harbour," which are to the effect that "at the Spit Buoy the first four hours of the flood run east-south-east towards Langston Bar." During the above period the tide runs strongly, and therefore under the lee or east-south-east side of the fort there would be comparatively still water, and a deposit would assuredly take place in it of all sand previously held in suspension by the current of the flood-tide.

The Sailing Instructions proceed to state, that "on the fifth hour of the flood it turns and sets weakly towards Southsea Castle, and the remainder of the tide sets at the rate of about a knot towards the harbour."

From the above set of the governing current it is clear to me that the Spit Buoy Fort, if made even of the small external diameter of 200 feet, cannot have a safe foundation against the scour which will take place without the latter being of a diameter at its base of 637 feet, as per an-

* Vide Journal of the Royal United Service Institution, vol. v. p. 560.

nexed drawing; and as this mass of rubble will be directly opposed to the stream of flood, no question can in my mind, as a practical man, arise as to the great extent of deposit, or formation of a spit of sand, which will take place on the east-south-east side of the fort in question. The nature of the alteration or change in the contour of the sands has been drawn by me on the chart.

The Sturbridge Fort is proposed to be built on what is in reality the tail of the Mother Bank, although a flood-tide swatchway appears to separate it from the outer spit of the Mother Bank; and this fort will have to be built on a sand which has on it a depth of about 3 fathoms at low water of spring tides. This sand is of a most lively character, and has deep water close to it; the channel on the north side of the Sturbridge having 14 fathoms at low water, and that on its south side 10 fathoms.

The tides also run heavily over this shoal, so that it would not be safe to assume that a rubble foundation could be obtained, and maintained harmless from the scouring action of the tide, at a less depth than 6 fathoms at low water. This extra depth below the present surface of the shoal is however merely a question of cost, and it is only necessary to reason upon the effect of the presence of that portion of the work which will be above the level of the surface of the shoal.

If this fort be therefore made, like that on the Spit Sand, of a diameter of only 200 feet, its foundation will have a breadth of 637 feet opposed to the flood-tides which run strongly there for four hours from north-west to south-east. The result of the establishment of this obstruction to the tide in the shape of the Sturbridge Fort must therefore be that of a considerable extension of the shoal to the south-east of the fort, extending beyond the Sturbridge White Buoy, and filling up the useful 10-fathom anchorage ground.

The fort proposed at the Horse Buoy lies eastward of the sailing channel to Portsmouth, and therefore, although from the same causes it must have the effect of creating a deposit south-east of it, the latter will not produce any injurious effects upon the navigation, so far as regards the set of the first four hours of the strongest run of the flood-tide. During the last three hours of the tidal supply, or of that which comes into the harbour of Portsmouth and the roadstead of Spithead from the south-east, the obstruction will not be such as to produce any injurious effects.

The fort on No Man's Land Shoal will be certain to cause the formation of an extensive spit of sand in a south-easterly direction; but in this case I am of opinion that this new shoal will favour the defence of Spithead roadstead, as it will be the means of limiting the available sailing course for ships of large draught of water to the main channel between the Warner and the Horse Elbow Buoy of the Horse Sand; whereas at present they can pass, at or near high water, up the channel south of the Warner. The new spit of sand would in fact intercept their progress.

I may here observe, that a reference to the text of my Lecture "On the Advanced Seaworks for the Defence of Portsmouth," will show that I attributed to the erection of Langston Mole, and also to the fort proposed by me on the Warner, precisely similar effects to those which I have herein assigned to the forts proposed by the Royal Commission, viz. a deposit or accretion to the east and south-east of them; but that, so far as regards

defensive purposes, the result which would be produced would be useful, as I have just stated in respect to the shoal which would be formed to the south-east in consequence of the erection of the fort on No Man's Land Shoal.

No Man's Land Fort is the southernmost of the seaworks proposed by the Royal Commission for the defence of Portsmouth and Spithead, and does not diminish very materially in importance, even when taken in connection with the more advanced works in a seaward direction, proposed by Admiral Sir Thomas Maitland, on the Warner Shoal, and that of Langston Mole by myself; which latter I humbly conceive carries out in its integrity the view of the Royal Commission, and of many eminent naval and military men, that Portsmouth shall be made free from the danger of being shelled by the smaller hostile vessels which at present would find sufficient depth for them on the Horse Sand to approach near enough to throw their shells into Portsmouth Dockyard, and yet be out of the effective range of the fire from the five forts proposed by the Royal Commission.

The object of all who bear in mind the importance of preventing our principal naval station from being shelled, must doubtless be to keep the enemy's ships at such a distance from the arsenal that they shall not have the power, even while hotly engaged by our own ships, of taking the opportunity of at the same time throwing shells into Portsmouth.

However powerful might be the fire from the forts, if established on the Horse, No Man's Land, the Spit, and the Sturbridge Sands, it would not do to give an enemy the chance of fighting so close to our own arsenal. It will be too late to prevent the destruction of the arsenal if the fight occurred in Spithead Roads. The enemy's ships would be sunk or surrendered, but probably not before the firing of the arsenal had been effected.

It is this view which brings to Langston Mole and the Warner Breakwater the honour of support from the many highly distinguished naval and military men whose names I am allowed to mention as favourable to the construction of those advanced sea-works.

By the establishment of Langston Mole, and the breakwater on the Warner Shoal, it would become quite practicable to make use of floating booms or rafts to impede or foul the passage of a hostile squadron into Spithead Roads, a measure which would be extremely difficult and costly, and in fact almost impracticable, if the breadth of channel were only increased by the space across the Horse Sand of a full sea mile in breadth, over which, at tide time, ships of large draught would be able to pass.

By the construction of Langston Mole and the Warner Breakwater, aided by partially-placed obstructions in the shape of booms or rafts, an enemy's squadron, if not previously stopped seaward of the Warner, would certainly be arrested there, and brought to action out of shelling range of the dockyards, and would have to confine his attention to the then, to him, more engaging objects by which he would be surrounded.

Our plated defence blockships would run into and grapple with his ships, down anchor, and make them stand and fight it out, while their flanks would be exposed to an overwhelming fire from the ships lining

each side of the channel, or lying moored in the channel on the west side of Langston Mole and the Warner Breakwater.

In my previous Lecture I proposed to follow the recommendation of Admiral Sir Thomas Maitland to construct a fort on the Warner Shoal; but so exposed a situation during heavy weather from the south-east would be more fit for the site of a breakwater, behind which our ships could more effectually deliver their fire than could be done from the fort on which heavy seas would break. I also consider that any fort placed there or elsewhere, unless presenting a very large frontage, would be liable to sudden destruction by an active foe by the adoption of very simple means, and I therefore propose the substitution of a rubble breakwater of 400 yards in length, as per accompanying section, behind which, as in the case of ships moored in the channel at the back of Langston Mole, our ships would be able to pour over its crest a destructive fire with comparative impunity to themselves from the effects of a hostile return from ships steaming up the channel.*

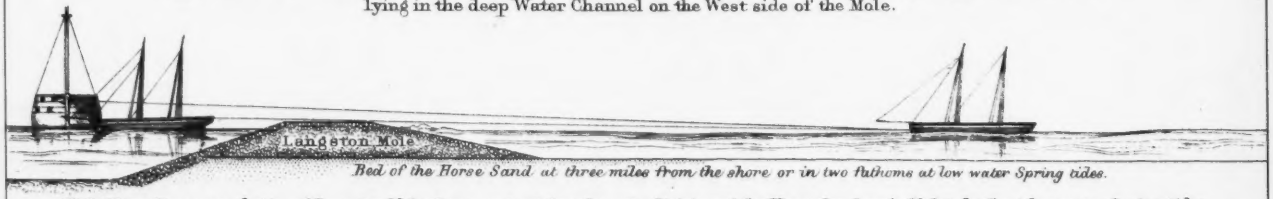
As regards the mode of attack upon the isolated forts of dimensions similar to those proposed to be erected on the edge of the Horse Sand in two and a half fathoms at low water, and on the Sturbridge in three fathoms, it is clear that, at tide time, there will at those places be ample depth for the passage of ships on both sides of those forts close to them; and we have now to consider some ready and simple means of blowing up or disabling those forts, even supposing they were plated with wrought-iron ten inches in thickness and backed with granite.

Imagine one of these circular forts of a diameter of 200 feet, but, for security against scour, provided with a rubble foreshore of 50 feet in breadth at the level of high water of spring tides, and further protected by long rubble slopes, forming a circle or mound of stone having a diameter of about 600 feet at the base, close to which latter there would be more than sufficient depth of water for a vessel of large draught to pass at or about high water,—if it be really necessary to interfere with the forts at all, considering the respectful distance at which ships will be able to steer clear of them, and that there will be no occasion to dance attendance upon them when the sole object of the attacking force would be the destruction of the naval arsenal, the ready means of levelling the walls of such a fort would be for two iron-plated ships to assail it, towing between them one or more coir warps, to the centres of which tow-ropes or warps there should be attached cylinders each containing about a quarter of a ton

* In the Report of the Royal Commission of Feb. 26, 1861, addressed to the late lamented Lord Herbert, there is a short description of the forts proposed to be constructed to defend Spithead and Portsmouth, as follows:—

"Sec. 15.—The forts now designed for erection on the shoals at Spithead will be of a peculiarly formidable description, and essentially different from any works that have hitherto been built. They will be constructed for 120 guns, in four tiers, of iron 10 inches in thickness from low-water mark, unless it is found expedient to carry the foundations of solid granite up to high-water mark. They will thus be individually in every respect invulnerable to any species of projectile, and impregnable by any force of ships that can be brought against them, or by any conceivable mode of assault. Their vertical walls, 60 feet in height, will render them inaccessible by boarding, a mode of attack suggested by the writer of the pamphlet [referring to that by Captain Coles], and the foreshore of the foundations will effectually prevent the approach of explosive vessels sufficiently close to cause damage to the works."

Approach to Portsmouth barred by proposed Langston Mole, which can be defended by Ships and Gunboats lying in the deep Water Channel on the West side of the Mole.



High Water Transverse Section of Langston Mole where constructed on the outer division of the Horse Sand or in 12 feet depth at low water Spring tides.

Approach to Spithead defended by block ships moored under cover of the proposed Warner Breakwater and Langston Mole.

Section at low water of Spring tides of the Warner Breakwater where constructed in a depth of three fathoms.

Scale One Inch = 160 Feet.

W. A. Brooke, C.E.

J.R. Jobbins

of powder. On nearing the fort the ships would only have to separate, one steering past the north and the other the south side of the fort, and in doing so the case of powder would suddenly be lifted out of the water and lodged against the iron face of the fort, the contact with which would fire the percussion fuses attached to the former, and down would go the fort as the attacking ships slipped the ends of the cable and passed safely in its rear. In one of my own operations for the removal of wrecks, a simultaneous discharge of four canisters, containing together 940 lbs. of gunpowder, placed against the hull of the "Lady Feversham" (a coal-laden ship of 900 tons burthen, which sunk in Shields Harbour in five fathoms at low water), lifted into the air one-half of that ship and its cargo, together with a column of water of 45 feet in height, being the depth of the canisters below the surface of the river at high water, or at the time of the explosion; so that practically I have very great faith as to what would take place upon saluting one of the proposed isolated forts with a good charge of powder. To insure success it would only be necessary to give a good dose of powder.

It is clear, therefore, that it would be utterly unsafe, and a waste of money, to construct small isolated circular forts unless the same are effectually protected against such a means of attack as I have suggested; and therefore I consider, that, in assigning to the fort a foreshore of only 50 feet in advance of its walls, I have taken a minimum in every respect as regards the efficiency of the fort and its cost; for it appears to me that the foreshore should be very extensive, and raised at least 10 feet above high water of spring tides, and with slopes of 5 to 1.

One of these forts, if founded in 3 fathoms at low water, or without going to a greater depth than that for its foundation, would, in that item of foundation alone, if raised to only 6 feet above high water, cost not less than 200,000*l.*; and I may safely affirm that the foundations of the forts which it would be necessary to construct in the hope of their being able to keep ships, or gunboats, from getting within shelling range of Portsmouth Dockyard will entail an expenditure of not less than 800,000*l.* This amount does not include the cost of the foundations for the forts on the Sturbridge and No Man's Land Shoals; which forts in themselves offer no defence against Portsmouth being shelled.

A reference to the chart will make it clear that to keep ships and mortar vessels from getting within shelling range of Portsmouth Dockyard, in addition to the two forts proposed by the Royal Commission to be built on the Horse Sand, it will be necessary to construct two other forts more to the eastward, or in fact nearly on the very line proposed by me to be taken as the proper direction for Langston Mole; the northernmost fort being placed equidistant from Cumberland Fort and the Royal Commission Fort on the centre of the Horse Sand; and the southernmost fort equidistant from the latter and the fort proposed to be erected near the Horse Buoy; their exact positions being the centres of the red circles of 1,000 yards radii on my outer line of defence.

In the foregoing observations on the foundations of the forts proposed by the Royal Commission, in the absence of any published detail of the mode proposed to be adopted, beyond the mere fact that it is understood that the forts are to be of a circular form, of a diameter of 200 feet, and faced with

wrought-iron plates of a thickness of 10 inches, I believe that I have acted fairly in assigning to their foundations a mode of construction which will be safer and more economical than any other which can be carried out. It would be possible to carry the iron forts upon screw piles, or upon a series of cast-iron cylinders, as is, I believe, proposed by a member of the Institution of Civil Engineers, but either of those plans would entail a much greater cost, and would not be secure against the scouring effects which would be produced by the interposition of the work to the strong run of the tides of both ebb and flood. If the very useful invention of that experienced civil engineer Mr. Gibbs — who patented about 30 years ago the system of procuring foundations by cast-iron cylinders, such as we see now executing within a quarter of a mile of the walls of this Institution in the form of the piers of the new Hungerford Railway Bridge— were adopted, there would be not the less a necessity for protecting them with a rubble foreshore. In fact it would be a most dangerous mode of construction to found the forts upon any system which would leave them exposed to the scour of the tides, or would render them liable to be destroyed by the explosion of large masses of powder.

I have already shown how practicable it would be to lift the explosive charges of powder to the base of an iron-cased fort, although that base were raised several feet above the level of high water of spring tides, and therefore it will be at once apparent how much more easy it would be to blow up a fort whose walls are carried up vertically from deep water, or supported either upon cylinders of cast-iron, or by screw piles from the level of low water.

By the provision of an extensive rubble or rock foreshore in advance of the iron forts, or the most effective mode of resistance, I am relieved from the accusation in "Tom Thumb," that "He made his giants first and then he slew them," because it would be enough to augment the height and width of the foreshore to render the explosions of powder comparatively harmless. This increase of the foreshore would, however, vastly add to the cost of the rubble foundations, which will be onerous enough even with the limited dimensions which I have assigned in order to keep down the cost of the isolated forts, and which I purpose hereafter to detail when contrasting the same with the estimates for Langston Mole and the Warner Breakwater.

The 200,000*l.* must therefore be looked upon as the minimum expense which will be incurred in obtaining a proper foundation for each of the forts proposed by the Royal Commission, and will be far below what must be spent to obtain one for the fort on the Sturbridge Shoal.

I trust that in my comments on the proposed circular forts, which have, in all probability, been adopted by the Royal Commission simply on account of the greater cost of the superior system of defence which from the time of Vauban up to the present day has universally been admitted by all scientific men as the best, I shall not be considered presumptuous in thus making myself the humble means of expressing the opinions of all those who know the high value of forts when planned by military engineers unfettered by cost: in the words of Major M'Crea of the Royal Artillery, "The only way in which I can understand that forts can be dangerous is, when the ships passing them are exposed to their direct

cross fire;" and I will add, that that cross fire should be delivered from batteries whose faces should be of sufficient length, or the distance between the guns such as to give the artillerymen a chance of seeing the object they have to aim at.

The fire from the small isolated circular forts (for, after all, they are only martello towers upon a larger scale) will be completely obscured after the first discharge of their own guns; and, when the wind blows from any point between north-west and south-west, an enemy's flotilla advancing to the attack would be completely obscured. If, again, the wind blew from the opposite quarters, or between north-east and south-east, the small available number of ports of these circular forts would be equally obscured, and the object to be struck could only be guessed at by the flash from the guns; and thus the powerful artillery of the fort might be delivering its fire upon a small gunboat in lieu of a frigate, which was at the same time rapidly advancing under cover of the veil of smoke.

Captain Coles, of the Royal Navy, has in his pamphlet demonstrated that, by taking 1,000 yards as the limit of the effective range of even a 100-pounder Armstrong gun against a plated frigate, the forts recommended by the Royal Commission are too distant from each other to effectually command the sailing channel between them; as will be manifest by reference to the chart, where the strong red lines described by a radius of 1,000 yards from the Horse Shoal Fort and the fort proposed on No Man's Land Shoal leave a free channel of about 400 yards clear for the passage of an enemy's ships; which channel, however, rapidly expands into a wide and free channel, owing to the diverging nature of the fire from a circular fort. A ship would be through this narrow channel before a second shot could be fired at her from each of the guns of the forts.

Hence the advantage of batteries disposed so that a ship while approaching would be compelled to remain for a considerable time exposed to a direct fire. Steaming along at the rate of ten miles an hour, she would give no chance of the guns of the fort being re-laid at her after the first discharge.

This brings us back to the position, that the line of defence should be confined to the smallest possible limit of breadth of channel; and this, in the case before us of the defence of the approach to Spithead, can only be attained by the establishment of a permanent barrier across the Horse Sands and a breakwater on the Warner Shoal, which, limiting the available channel to a breadth of 5,500 feet, will enable it to be in time of war rendered difficult to pass by mooring rafts or booms in it, the exact position of which would be unknown to an enemy, inasmuch as they would be capable of being placed on either side of the channel, or in its centre, so as to compel those ships of an enemy which succeeded in passing them, at all events to previously undergo the ordeal of a close and concentrated fire from the ships moored in the channel at the back of the Mole and the Warner Breakwater.

During heavy weather from the south-east the moorings of the rafts and booms could be slacked away, so as to bring them under the shelter of the Mole and the Warner Breakwaters. In time of war, additional obstructions might be presented by mooring other rafts seaward of, or in advance of, the outer line of defence of the Mole and Warner, so as to

keep an enemy longer under their cross fire; and, in fact, the several rafts might be so arranged as to prevent a direct course being made by an enemy into the harbour. These could readily be slipped from their screw moorings during heavy weather from the south-east. By those advanced sea-works of Langston Mole and the Warner Breakwater, Spithead Roadstead would be converted into a perfect harbour; and its entrance would become as safely defended as the western channel of the Solent at Hurst Castle will be by the construction of the judiciously arranged works planned by the Royal Commission. It is well known that the area of deep water is exceedingly limited in Portsmouth Harbour, when regard is had to the vast increase of colossal ships of war which is being made, for which ships no station is so convenient as Spithead when the British Channel has to be defended.

Langston Mole and the Warner Breakwater would present as good a defence as could be made to the entrance of Southampton Water, of which Major M'Crea, in his able letter, says:—"If the passage across Southampton Water at Calshot Castle could be made impassable, so as to secure a dockyard eight miles up at Southampton, where our future iron navy could securely retreat and repair, then the value of such an outlay, however vast, might be well appreciated by the nation."

Just so, I submit, would be the expenditure upon Langston Mole and the Warner, which, at the cost of less than a million of money, or, in fact, at less than what must be disbursed upon the foundations of the isolated forts proposed by the Royal Commission for the defence of Portsmouth, would provide the desideratum of Major M'Crea, but without entailing one-tenth of the cost of erecting new establishments at Southampton, to supply the place of those now existing at Portsmouth.

From observations on the set of the streams of flood and ebb recorded on the Admiralty Chart, the following deductions may be made:

1st. That the main, or strongest, current of the flood-tide comes through the northern channel, or by the Solent Sea, for the first five hours of the tide, and that that stream receives an augmentation of its volume during the remainder of the natural duration of its flow of 6 hours and 12 minutes from the tidal wave which comes round the back of the Isle of Wight and enters Spithead from the south-east.

2nd. That the directions of the flood currents of both the northern and the southern channels are not such as would be intercepted by any work like the mole proposed east of the entrance into Langston Harbour, so as to impede the flow into Portsmouth or Langston Harbours.

3rd. That the effect upon the northern flood current by the interposition of Langston Mole upon its progress, after passing the mouths of Portsmouth and Langston Harbours, must be that of accumulating the water against the concave face of the mole and forcing it up to a higher level in those harbours.

4th. That the effect of the presence of the mole upon the tidal stream which enters Spithead from the south-east must at least be innocuous, as the supply will pass easily up the spacious channel which will be left between the mole-head and the north shore of the Isle of Wight, the same being 14,000 feet in breadth, or ample for the full volume which is required to fill the Solent and its tributaries; and because the mole itself lies

eastward of the course which the tidal wave takes, which now affords the supply on the latter part of the flood-tide.

The tidal stream in Langston Harbour, where confined in its course, has in its natural state a depth of from 5 to 7 fathoms at low water of spring tides, and on the ebb the water rushes out during the third, fourth, and fifth hours with a velocity of 3¼ knots per hour, its course being towards the southern channel, or eastward of the Isle of Wight, and its velocity such as will ensure a deep channel alongside of the concave face of Langston Mole, sufficient for our largest line-of-battle ships to lie afloat there at the lowest ebbs. In this capacious channel, ships moored in it would be covered by the rubble masonry of the mole, the seaward face of which would form a glacis, over the crest of which their artillery would be able to deliver their fire in any direction, either to prevent the approach of gunboats to it, or the shore of Hayling Island to the eastward.

In this channel our old line-of-battle ships would, in fact, as aforesaid, become moveable batteries, and as formidable as if plated with iron, so effectually would their hulls be masked by the mole.

The almost immediate effect of the erection of the mole would be to considerably shoal the water eastward of it, so that it would be impracticable for even a gunboat to get at high water within shelling range of Portsmouth Dockyard.

The mole would thus effectually protect the shore from any attempt at a landing on it anywhere within the range of the ships' batteries; which useful range against gunboats we will assume to be one nautical mile, or abreast of the village of Hayling; and, as the deep-water channel of the eastern stream in Langston Harbour is sufficient for our block-ships, it would be impossible for an enemy to establish any batteries on Hayling Island near enough to shell the naval arsenal of Portsmouth without being within point-blank range of the guns from our ships, as the latter would be moored in a channel at a distance of from four and a half to five miles eastward of the dockyards. This will be fully acknowledged when it is remembered that the eastern shore of Langston Harbour is above five miles distant from the eastern side of the dockyards, and the latter will be, therefore, unassailable on the landward side nearer than Portsdown Hill.

Batteries would doubtless be established at other places on the coast, so as, in like manner, to render the establishment of a landing difficult westward of Selsea Bill, and thus place a long day's forced march between Portsdown Hill and the shore eastward of Selsea Bill, and give sufficient time for us to be enabled to concentrate our forces, to intercept, and save the enemy the trouble of breaking ground on Portsdown Hill.

To complete the seaward defence of Portsmouth it will, however, be still necessary to guard the channel of 14,000 feet in breadth, which will remain between the end of Langston Mole and the northern shore of the Isle of Wight, near Nettlestone Point. This object will be effectually carried out by a portion of the works recommended by the Royal Commission on the National Defences, combined with another on the Warner Shoal, a most advantageous position, as lying immediately between the south end of Langston Mole and the Isle of Wight, the northern edge of the Warner being only nine cables' length, or little more than a statute

mile, distant from the mole-head. The site of this shoal was proposed by the gallant Admiral Sir Thomas Maitland as a fit place for the erection thereon of a fort seaward of those recommended by the Royal Commission. Its value, however, is immensely enhanced when combined with a work like Langston Mole, which will have the effect of compelling an advancing foe to pass under its fire.

The depth of water on the Warner Shoal is from two and a half to three fathoms at low water of spring tides; this shoal I am of opinion will however be rendered more useful by being raised up to the level of a few feet above high water of spring tides, so as to form a breakwater, under the shelter of which our wooden walls would be as effective as those proposed by me to defend the approach to Langston Mole.

The length of this mole on the Warner may be at first made of four hundred yards, and its effect will be, as aforesaid, to form a shoal lying in front of it, and bearing north-west and south-east; such, in fact, as will ensue by the erections proposed by the Royal Commission on the Sturbridge, Horse, and No Man's Land Shoals.

These eastward extensions of No Man's Land and the Warner Shoals will add materially to the defence of the approach to Spithead, as they will, even at high water of spring tides, render it impracticable for steam frigates to approach by any other channel than that between Langston Mole and the Warner, and the second line of permanent defence, consisting of the forts on No Man's Land and the Horse Sands; the whole defence consisting of a very formidable quadrilateral.

Another advantage in this defence is, that, if an attack be made on it during the flood tide, the latter runs here so slowly as to be of little service in accelerating the passage of ships, the greatest velocity of the current from the south-east being only one knot per hour.

The cost of Langston Mole necessarily depends upon the nature of the work: thus, a chalk and rubble reef (as per sections) run up to the level of 6 feet above high water of spring tides, with sufficient seaward slopes to enable it to remain permanent until it became drifted up with sand and shingle, would not cost more than 500,000*l.*; and it may be certainly taken as a matter of reliance that this result would rapidly follow the protrusion of the Mole over the shoal ground of its site. Witness the immense annual accretions on the shore of Hayling Island of both shingle and sand. In fact, so great is the effect of gales from the south-east in driving up shingle, that it would be only necessary to erect a jetty of iron piles and sheet-piling over the line of the intended mole to insure its being rapidly buried up on its seaward side in a mass of shingle and sand. If this construction were necessary on account of despatch, one-half of the length of the mole might be raised to the level of high water of spring tides by a single length of iron piling, and the southern division completed by two sorts of piles, the first brought up to the level of half tide, and subsequently raised on the accumulation of shingle which would be produced by driving the lower range of piles. The facility with which Langston Mole would be completed, owing to the shoal nature of its site, is such, that it may be safely stated that it could be run out to its full length over the East Winner and Horse Sands, before either of the piers at Dover or Alderney could be extended 600 feet further seaward.

I shall confine myself in my estimate to the good old-fashioned system of construction of breakwaters by rubble and chalk, with long seaward slopes, and assume that it would be necessary to provide the latter of as permanent a character as if really exposed to seas such as the Plymouth and Cherbourg breakwaters have to withstand. In this case Langston Mole is proposed by me to be raised to the level of six feet above high water of spring tides, with seaward slopes of 6 to 1, and on the harbour side with slopes of 3 to 1; precaution being also taken to provide rubble for forming the concave face of the six-fathom channel, which will be scoured out by the discharge from Langston Harbour on the creation of the mole. The mole to have also a top breadth of 70 feet, to give room for portions of it being capable of being raised to a greater height in order to more effectually mask the hulls of our line-of-battle ships moored in the channel along. As a simple breakwater or mole, a top breadth of 22 feet would be sufficient.

The total cost of such a mole will not exceed 727,827*l.* if made of a top breadth of seventy feet and of a length of 6,200 yards; and of 491,699*l.* if of a length of 5,000 yards; which latter, if approved of, would probably be the length at first ordered to be constructed and contracted for. In both of the above estimates the large amount of 20 per cent. has been added for contingencies.

To complete the outer line, or advanced sea-works, the cost of the breakwater of 400 yards in length on the Warner must be added; this length will mask four old line-of-battle ships. In this case, if partly made of chalk blocks transferred from the end of Langston Mole, covered with a mass of Portland or Swanage stone, or in fact strongly cased with rubble as per annexed drawing, the estimate would be:—

	£
For chalk for the core, 221,200 cubic yards, at 5*s.* . .	55,300
For stone for facing the same, 163,600 cubic yards, at 12*s.* 6*d.*	102,250
	157,550
Add 20 per cent. contingencies . .	31,510
	£ 189,060

Cost of Langston Mole, 6,200 yards on the Horse Shoal .	727,827
Breakwater on the Warner	189,060
Making the total cost of the outer line of defence .	£ 916,887

If however it be considered advisable to form the Warner Breakwater altogether of rock or rubble work, this, with 20 per cent. for contingencies, would amount to . .	288,600
Add Langston Mole, for its full length	727,827
Total cost of the outer line of defence	£1,016,427

So large an amount having been provided for contingencies, both in the price of the work and the bulk of material, it may be relied on that one million sterling will form both Langston Mole and the Warner Breakwater; which, if defended by our wooden walls alone, and the channel between guarded by iron-plated ships, will afford a much more effective defence than if the whole of the five forts proposed by the Royal Commission were constructed. It has been proved, however, that if the whole five of the forts were constructed as recommended by the Royal Commission, viz.: two forts on the Horse Sand, one on No Man's Land Shoal, one on the Spit Sand, and one on the Sturbridge, they would not be sufficient to prevent a squadron of iron-plated ships from running between them and taking up positions from which they could shell Portsmouth Dockyard and burn both Portsmouth and Portsea, without being within a mile and a half of the guns of the proposed forts.

It has also been proved that those forts would not prevent gunboats, or other vessels of light draught of water, approaching from the eastward over the shoal ground of the Horse, and also getting within easy shelling range of the dockyard and Portsmouth; while at the same time they would be out of effective range of the fire from the five forts proposed by the Royal Commission, and also of the shore forts. To prevent an attack by gunboats, at least the two additional forts in the line of Langston Mole before noticed must be constructed on the eastern verge of the Horse Sand, and those works alone, viz. the two additional forts, would cost more than Langston Mole.

The question of the cost of the forts proposed by the Royal Commission should be carefully considered, as well as the effective defence which they would procure, or rather the amount of it. Both would be very easy to estimate closely, provided the plans or mode of construction were made public; it is however enough that we know that they are to be of a circular form, with a diameter of 200 feet at the level of high water, to be enabled to readily ascertain, at all events, what their foundations alone would cost. These forts, if they are not to be exposed to be blown to pieces by the explosion of large cases of powder towed to their bases by vessels steaming on each side of them, as before mentioned, must be provided with a broad and rugged foreshore of rubble, carried up to the level of at least six feet above high water of spring tides, and with slopes so much inclined as to prevent vessels of fifteen feet draught of water getting within a less range than 150 feet of their bases at high water of spring tides. This will be effected by a foreshore of fifty feet in breadth, and with slopes of five to one from the level of six feet above high water to low water of spring tides, and below that level with slopes of three to one. If this rock or rubble-work base for the fort be founded in only eighteen feet depth at low water, the cubical yards of stone required will be 276,230, which, at 15*s.* per yard, including contingencies, will amount to 207,172*l.* It will be here remembered that I have estimated the rock-work on the Warner at 288,600*l.* if raised to the same level of six feet above high water of spring tides.

In round numbers, the bases of the forts recommended by the Royal Commission will each cost not less than 200,000*l.*, and if they are to be surmounted by iron forts, provided with ten-inch plates or walls, and carried up as proposed to the level of sixty feet in height above low water,

the superstructure of each fort will not cost less than 200,000*l.*, and therefore each fort not less than 400,000*l.*; and, after all, what will be the amount of the effective fire of each fort? The circular form which has been adopted is the weakest as regards the number of guns which they will be able to bring to bear against a hostile force advancing against them. If the forts consist of three tiers of batteries, not more than four guns in each tier will be effective against an approaching ship, or not more than would be better delivered from a single corvette's broadside.

The corvette's battery of twelve or fourteen guns would have the advantage of being comparatively clear of smoke, but who will pretend that any precision of fire can be expected or sustained for any length of time where three or four tiers of guns are simultaneously discharged? Surely the effect must be the same as in a three-decked ship, where the order is so frequently given to cease firing, in order to allow the smoke to clear away.

The exceedingly limited face which the effective fire from a circular fort gives will allow it to be easily masked by the fire of two or three gunboats, the smoke from which would be such as to shroud the advance of the more formidable frigates, which would form a portion of the attacking squadron.

If Sebastopol or Cronstadt forts had been merely circular, instead of presenting long lines of formidable batteries, nothing from them would have prevented the approach of our wooden walls.

Notwithstanding the great weight of the opinion of the Royal Commission on the question of circular forts against the usual long batteries which for several centuries have entirely superseded circular forts (except in the cases of martello towers, where a long line of coast has had to be defended at a small comparative cost), I do not hesitate to declare my humble opinion as opposed to the construction of the isolated forts proposed by the Royal Commission for the Defence of Portsmouth and Spithead, while I subscribe willingly to the propriety of their advice in recommending the construction of certain permanent works or forts, in aid of the defence by floating batteries. If forts are to be built, the best positions will be those selected by the Royal Commission at the Warner, No Man's Land Shoals, and at the Sturbridge; but the latter would have the injurious effect of causing the formation of a long spit of sand tailing down from it in a south-east direction, and shoaling up some of the best anchorage ground of Spithead Roadstead.

In lieu of the circular fort proposed to be constructed on No Man's Land Shoal, which would not give so good a fire as from a single iron-plated corvette, I believe that it would be more advantageous to construct upon it a fort of much larger dimensions, with two lines of batteries to defend the approach to Spithead Roads from the south-east, whose junction would form a re-entering angle of 135°, or thereabouts, the northern face or battery bearing north-north-east and south-south-west, and the southern one from north-north-west to south-south-east; the northernmost battery having a length of 600 feet, and the southernmost also 600 feet of effective length for the position of guns, thus affording ample space for working 55 heavy guns on the lower or casemated tier, and as many mounted *en barbette*. The fort should present to an approach from south, by compass, two similar faces of 400 feet each, and similar

faces also on the opposite or north side, which latter would completely command the roadstead of Spithead.

It has been, I believe, determined that only three of the forts proposed by the Royal Commission shall be constructed, viz. one on the southern verge of the Horse Sand near the Horse Buoy, one on No Man's Land Shoal, and another on the Sturbridge Shoal. But, inasmuch as at high water of spring tides there is a depth of 22 feet 6 inches over the Horse Sand at a nautic mile north of the proposed fort at the Horse Buoy, there will be no obstruction presented to the approach of the larger class of despatch gunboats, or even of the smaller corvettes. Aware of this fact, the Royal Commission evidently entertained a strong desire (as appears in the evidence) to establish a barrier of stone between the fort at the Horse Buoy, proposed by them, and Cumberland Fort.

I have shown that the five forts proposed by the Royal Commission will cost not less than 400,000*l.* each, and that, on account of their circular form, they will not be so effective as five corvettes moored near the same positions. Their aggregate cost will therefore be two millions, and for that sum I submit the effective defence will not be at all equal to the outer line of defence proposed by me at a cost of one million, viz. by the formation of Langston Mole and the Warner Breakwater.

In conclusion, I think that, now that the strength of England has been partly put forth, and that in a few months we shall be in possession of a commanding force of iron-plated ships of war, economy may be very fairly tried in reference to the outlay upon the projected iron forts, inasmuch as, by the establishment alone of the outer line of sea defence proposed by me, viz. Langston Mole and the Warner Breakwater, assisted by floating booms or rafts to render the channel more intricate, the wooden walls of Old England may be safely entrusted with the defence of Spithead and Portsmouth, while our ironsides may keep the Channel, or, when occasion arises, blockade those ports which require their especial attention.

Lastly. I have but a short time to notice the mode of construction now going on at some of our refuge harbours, as they are called. Alderney is being formed with lofty vertical walls, or nearly so, from the level of 12 feet below low water of spring tides, and from low water upwards is completely exposed to the fire of artillery. At a long range a few gunboats would undercut and topple down by a day's fire more of the masonry than has been built in a year. The works at Alderney are now being constructed in above 12 fathoms at low water. Dover Pier is now also being built with vertical walls, from the level of above 7 fathoms in depth at low water of spring tides, and presents a capital target for a gunboat to practise at. That pier is now costing about 1,200*l.* for each yard in length; and three or four well-directed shots from one of Armstrong's 100-pounders at a range of a mile and a half would bring down each yard in length of the granite facing, leaving it a ruin; and its destruction would be completed by a few shells delivered into its concrete core. Cherbourg Breakwater would be a still easier work to destroy, as its construction has not been of the massive character of the piers at Alderney and Dover; and therefore Cherbourg is not a standing menace, for its face wall seaward, where defended by batteries, would be a ruin after a day's practice at it with

shot and shell from our gunboats. It will be seen, from the above remarks on the circular forts, that I do not concur in the views of those gentlemen who consider that it is only necessary to make a work invulnerable in itself, in order to provide the best means of defence. This system carries us back to about the conclusion of the middle age, when defensive armour became so perfect that the wearers of it became incapable of hurting each other; and great battles, as they were called, took place with very little bloodshed on either side. Just so will probably be the effect of the heavy plating of our ships of war, which, in their present mode of construction, weakens instead of adding to the strength of their frames when opposed to the most formidable foe they will ever have to contend against—a tempestuous sea lasting for forty-eight hours together. In my humble opinion it will be better to remain satisfied with making our plated ships proof against shell alone, which 3-inch plates will effect, rather than encounter the enormous cost of iron plating, which, to resist the bolts of the improved artillery of the present day, had need exceed even 6 inches in thickness. Probably, in the long run, there will be greater loss of life by over-plating, over-weighting our ships of war, than in allowing shots of one or two hundredweight to pass clean through them, as did the 32-pounders in former fights. Recent experiments have shown, that, to effectually resist the bolt from a 100-pounder Armstrong gun, or, at closer quarters, the shot from an old 68-pounder gun, the plates with which forts or ships must be covered, must be of the very best iron, and have a thickness of five inches; but the experiment has not yet been carried out to the extent of ascertaining how far such plates would be able to withstand a broadside from a ship like the "Warrior," which could deliver a concentrated fire of twenty-four 100-pounders.

Bearing also in mind that 300-pounder Armstrong guns are now about to be tried—and few can doubt their eventual perfection, credit must be given to the naval and military advisers of our Government for the suspension of their decision as to the erection of forts, which, if even plated with 10-inch iron, at an enormous cost per ton, would probably be found to fail under the concentrated fire of such formidable artillery. Such artillery may, perhaps, also be considered of too valuable a nature to be allowed to be cased up in forts whose fire it may not be necessary to approach in order to effect a proposed object of destruction.

On the whole I must confess that, looking at the enormous strides which are being daily made in the improvement of artillery, the Government must also be allowed credit for judgment in giving a prior consideration to the construction of floating means of defence, and that, in the words of Major M'Crea, of the Royal Artillery, "the question between forts and ships cannot be considered abstractedly as a question of expense. If it were positively ascertained that the former were far better than the latter, or that they really could do their work, and prevent the entrance of an enemy to Spithead, I do not believe the country would cavil at any estimate, however enormous; nor is a high value to be placed on the fact that these forts can be themselves made invulnerable. It is not the amount of safety to the gunners within their *enceinte*, but the damage they can cause in so many minutes to an enemy, under circumstances of especial difficulty, which alone must be considered. Their merits in this balance are wanting. Iron-cased

ships, or forts in motion, can alone contend, with a reasonable chance of success, against similar forts in motion."

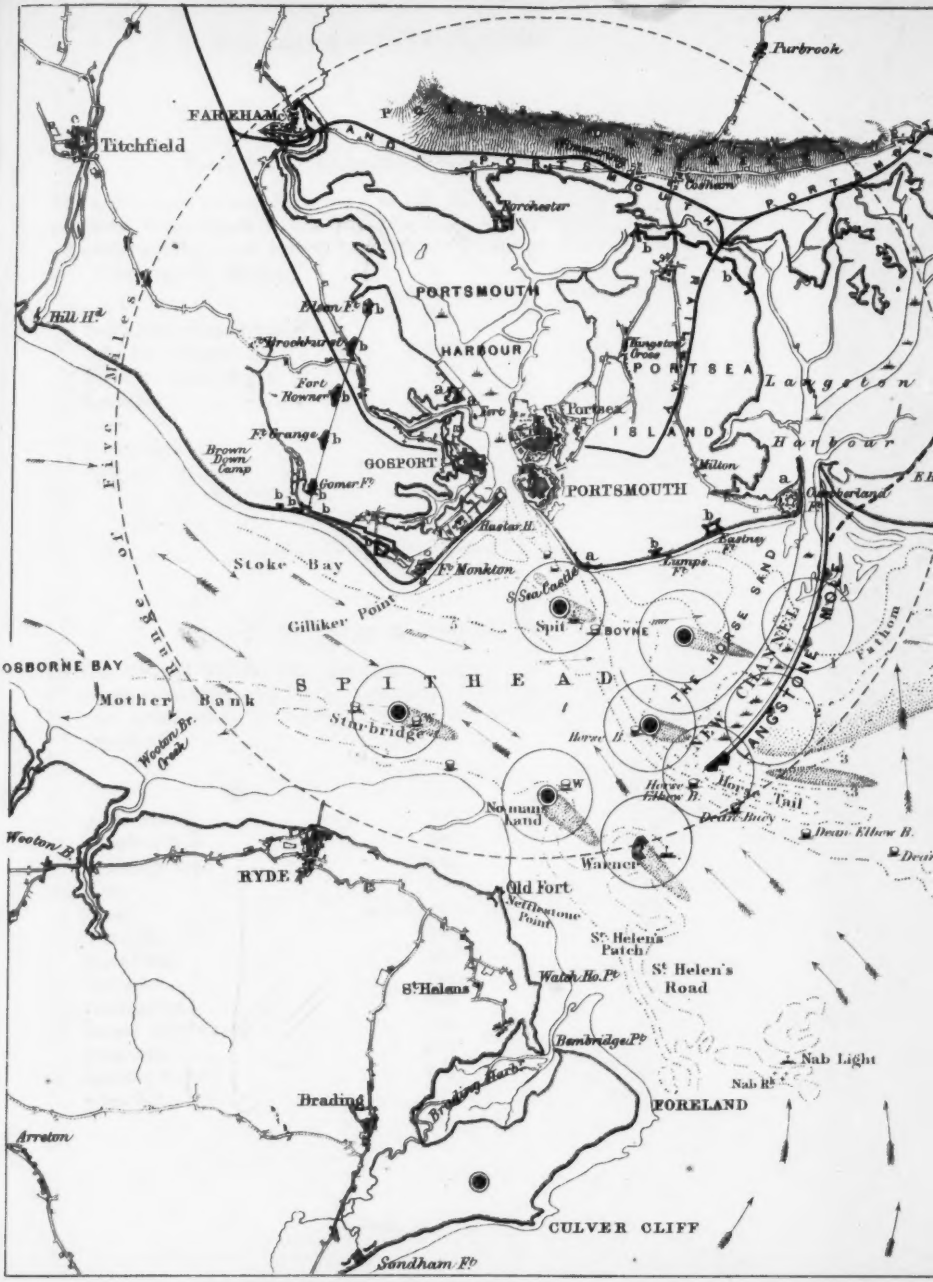
Coinciding with Major M'Crea in the above, I have carried his argument further, and applied it to the floating forts or ships, which in my opinion it is not advisable to attempt to make invulnerable, except as against shells, the effects of which they alone have to dread.

If, as I believe, guns will be constructed to throw bolts of three hundredweight, it will be only necessary to establish them upon floating batteries protected by the glacis of Langston Mole and that of the Warner Breakwater, to give the most effective and economical means of defence to the roadstead of Spithead. To the fire of such powerful artillery it will be nearly useless to oppose framework of any description in small masses, which will be exposed to a concentrated fire; and, in fact, in the present day, the defence afforded by the glacis of a fort becomes of infinitely greater importance than when the attack was limited to the fire from 18-pounder guns. Hence arises, in my humble opinion, the great value, in the shape of efficient protection, of the Warner Breakwater and Langston Mole; and hence also a doubt on my mind whether it would not be advisable to construct a breakwater also in advance of the fort proposed to be built on No Man's Land Shoal, leaving however a 5-fathom channel between it and No Man's Land Fort, in which channel gunboats or ships could lie, and in fact possibly supply the place of the proposed fort.

If this breakwater were made to run, as per plan, in a line bearing south by compass from the white buoy of No Man's Land, it would pass over 5-fathom water, and would keep clear of any deposit in the channel behind it, as it would be in the true run of the tide there. This advanced work would remedy the only existing defect of the position of No Man's Land Fort, viz. by enabling a fire to be brought to bear 400 yards nearer to the channel which has to be defended, than by the site selected by the Royal Commission, and make the main channel in fact of about the same breadth as between the Warner and Langston Mole.

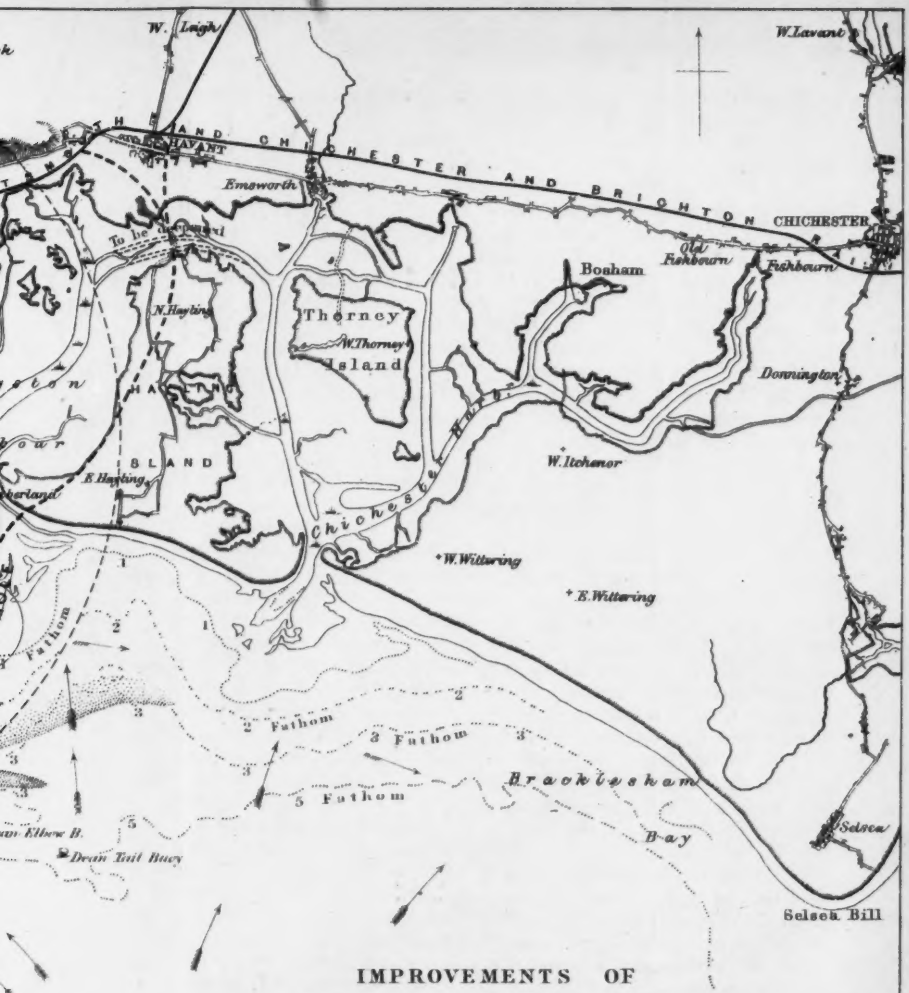
I have elsewhere shown that the whole of the site of the Horse Shoal between Southsea Castle, the buoy of the Horse Shoal, and the western side of the channel leading to Langston Harbour, will rise considerably in height after the erection of Langston Mole, so that this very effect will supersede to a great extent the necessity of any fort on the Horse Sand, particularly if, as I have suggested, the defence on the south side of the channel be brought 400 yards nearer; and thus, in addition to the defence of the line of advanced sea-works proposed by me, it will only probably be thought necessary to have a powerful range of batteries at No Man's Land Shoal, as a reserve or second line of defence, inasmuch as the channel abreast of it will be capable of being also additionally secured by booms or rafts, as suggested for the advanced line of works.

Finally, after all that has been endeavoured to be said by myself so much in favour of my own project, it is in itself nothing more than might naturally be expected to emanate from one whose practice happens to have been for above thirty-five years especially devoted to that department of engineering which would lead to projecting Langston Mole as a harbour improvement, and which casually has been brought to be subservient to military purposes, of the value of which the Members of your useful Institution must be the best judges.



Note. *The Early Flood Current is shewn thus* ⟶
The Later Flood " " " " ⟶

1 ¾ ½ ¼ 0 1 2



IMPROVEMENTS OF
PORTSMOUTH, LANGSTONE AND CHICHESTER HARBOURS AND SPITHEAD ROADSTEAD.

By W. A. Brooks, M. Inst. C.E.

1862.

Explanation { a.a.a. *Old Fortifications*
b.b.b. *Works in course of Construction.*

SCALE.

J.R.Jobbins

TABLE No. 1. (From the Admiralty Chart).

Of the times of low and high water at full and change days of the coast tidal wave which travels from the west side of the Isle of Wight through the strait between the Isle of Wight and Hurst Castle, and thence up the Solent.

	Time of Low Water. h. m.	Time of High Water. h. m.
In the North Channel west of the Isle of Wight	3·30	9.40
Yarmouth (Isle of Wight)	3·30	10·00
Lymington	4·00	10·25
Cowes	4·10	10·45
Southampton	4·00	10·30
Ryde	4·15	as below in Table No. 2.

TABLE No 2. (From the Admiralty Chart).

Of the times of the low and high water at full and change days of the coast tidal wave, which, on being split at the Needles, travels round the south coast of the Isle of Wight, and enters Spithead from the south-east.

	Time of Low Water. h. m.	Time of High Water. h. m.
At the Needles	3·40	9·46
Atherfield Point	3·40	10·20
Bembridge Point	4·00	11·00
Ryde	4·15	11·20
Cowes	as in Table No. 1.	11·45
Yarmouth	Ditto	12·00
Hurst Castle	Ditto	12·00
Lymington	Ditto	12·15
Southampton	Ditto	12·45
Abreast of the Warner	4·30	11·20
Portsmouth	4·30	11·40
Langston Harbour	4·40	11·40
Selsea Bill	—	11·45

Friday, March 7th, 1862.

Major-General the Hon. J. LINDSAY, M.P. in the Chair.

THE MOTION OF PROJECTILES FIRED FROM RIFLED ORDNANCE, AND THE ADVANTAGES OBTAINED BY THE EMPLOYMENT OF SUCH PIECES.

By Major C. H. Owen, R.A. Professor of Artillery, Royal Military Academy, Woolwich.

The subject that I have to bring before you to-day is so extensive that I can only be expected to give a very slight sketch of it in the short time allowed for a single lecture. I must, therefore, ask you to excuse any omissions that I may be compelled to make, as I should wish to dwell more particularly on those points which are of the greatest practical importance.

The art of gunnery appeared a few years ago to excite but little attention in this country; while many simple people not only hoped, but believed, when they witnessed the success of our first Great Exhibition in 1851, that gunpowder could scarcely again be required for warlike purposes—at least in Europe. However, the constant revolutions and wars that have occurred during the last few years have no doubt induced all but the "Peace-at-any-price party" to take some interest in an art the cultivation of which is so manifestly essential to the safety of a state.

In fact, shooting has now become a national amusement, and a vast amount of mechanical skill has lately been displayed in the invention and manufacture of improved firearms and projectiles of all kinds. Notwithstanding, however, the great interest taken in all questions concerning the relative merits of different firearms, we are as a people very ignorant of the science of gunnery. Yet, without some knowledge of its elementary principles, no opinion of any value can be formed, even from the results of the most careful experiments. Accounts of trials between different firearms are constantly inserted in the papers, and very rash conclusions often drawn by the public, every one thinking himself competent to give an opinion upon such apparently simple questions. One gun is said to shoot rather farther than another, and therefore it is the best; another gives more penetration, or has some other alleged advantage; or, to take a recent case—that of firing from smooth-bored and rifled guns at wrought-iron plates—in one of the trials the fire of the former produced more effect than that of the latter, and, therefore, it was immediately concluded that we had gained nothing by the introduction of rifled ordnance, and that, after all, smooth-bored guns are the best—a most absurd conclusion!

Projectiles are governed in their flight by certain mechanical laws, and hence the necessity of endeavouring to ascertain what these laws are; for, if absolute truth cannot be arrived at, a near approximation to it is obviously of very great practical utility. There is at the present time a complete surfeit of newly-invented firearms. Some of these are very valuable, and others practically useless, or very inferior to those that have been long in use; but the greater number are made quite independently of the actual requirements of the service for which they are intended—in fact, every inventor follows his own opinion as to the proper form of projectile, the velocity, the twist of the grooves, &c. Now, it is precisely these conditions of form, velocity, &c., which determine the accuracy of fire, the range, and penetration of a projectile, no matter what kind of gun is employed; and, therefore, it is highly desirable to ascertain, by direct experiment, the requisite conditions for particular purposes.

It should be clearly understood that there are two distinct questions, each of great practical importance, which now excite much attention. One relates to the projectile, and is more especially an artillery question; the other, relating to the gun, is a mechanical problem. It is necessary, first, to determine the conditions of velocity, form of shot, &c., requisite to obtain accuracy, range, and penetration—also the shape of projectile adapted to the destructive purpose for which it is intended; secondly, to contrive a gun which shall give a certain projectile the necessary initial velocity and velocity of rotation, and which shall combine excellence and simplicity of construction with the requisite strength, weight, and durability. In every case, when practicable, the gun must be made for the projectile, and not the projectile for the gun; and both, as well as all warlike *matériel*, should be of as simple construction as possible, for otherwise they will be liable to become unserviceable from derangement of parts, and the large bodies of men for whom they are provided will not understand or appreciate the various mechanical arrangements, and will, therefore, commit blunders in using them.

In my remarks to-day I shall not enter at all into the relative merits of different systems of firearms. In the first place, I shall consider the laws which govern the motion of an elongated projectile. I shall then endeavour to point out a few general principles derived from these laws. My concluding remarks will refer to the advantages obtained by the employment of elongated projectiles, instead of the spherical shot and shell previously used with smooth-bored guns, and the influence which the fire of rifled ordnance may be expected to exercise upon the operations of future wars.

Elementary Laws which govern the Motion of an Elongated Projectile.

It will be unnecessary to explain the nature of the motion communicated to a projectile when fired from a gun by the explosive force of the powder, or how that the shot is gradually brought to the ground by the action of gravity. It will be sufficient to remind you that the two forces of projection and gravity would together cause the centre of gravity of a shot to describe *in vacuo* a parabolic curve.

That the trajectory of a shot fired with a high velocity in the atmosphere

differs very considerably from a parabolic curve, in consequence of the resistance of the air, is a well-known fact; but I shall make a few observations on the circumstances upon which this resistance depends, for a consideration of these will enable us to understand why the ranges of projectiles fired from rifled ordnance are so much longer than those of shot from smooth-bored pieces.

Circumstances upon which the Resistance of the Air depends.—The resistance which a projectile meets with in moving through the atmosphere depends chiefly upon its velocity, and upon the magnitude of the surface it presents to the resistance.

Dr. Hutton found by experiment that the resistance of the air increases gradually up to a velocity of about 1,500 feet per second, when it varies as the 2·153 power of the velocity. The reasons assigned by Hutton for this gradual increase are as follows:—"The circumstance of the variable and increasing exponent in the ratio of the resistance is owing chiefly to the increasing degree of vacuity left behind the ball in its flight through the air, and to the condensation of the air before it. It is well known that air can only rush into a vacuum with a certain degree of velocity, viz., about 1,200 or 1,400 feet in a second of time; therefore, as the velocity is greater, the degree of vacuity behind goes on increasing, till at length, when the ball moves as rapidly as the air can rush in and follow it, the vacuum behind the ball is complete, and so continues complete ever after, as the ball continues to move with all greater degrees of velocity."*

In certain cases for the sake of simplicity, as in comparing the respective resistances to projectiles moving at different velocities, we may assume with sufficient accuracy for all practical purposes, that the resistance of the air varies as the velocity squared.

Retardation.—The velocity a projectile loses in consequence of the resistance of the air, or its "retardation," will, however, depend also upon its weight—being, in fact, inversely as the weight.

Elongated Projectiles less retarded than Balls.—Now, if two projectiles of similar weight but of different forms could be fired in vacuo with the same velocity, one would range as far as the other. In the air, however, any change in the form of a projectile not only affects the range but also the accuracy of fire. It will be sufficient here to notice the effect of form upon range.

If an elongated shot and a ball of equal weight be fired with the same initial velocity and angle of elevation, the former will be less retarded, and will consequently range farther than the ball, for the diameter of the elongated projectile being smaller than that of the ball, the elongated shot will not oppose so great a surface to the resistance of the air as the ball. For instance, if a 12lb. Armstrong projectile and a 12lb. ball be moving with the same velocity, the resistance of the air being assumed to vary as the squares of their diameters,

The diameter of the 12lb. Armstrong shot = 3 inches,
" " ball = 4·5 inches,
Therefore the resistances will be as 9 : 20·25, or 1 : 2·25.

* Hutton's 37th Tract.

From which it appears that the resistance opposed to the ball is more than twice that which acts against the Armstrong projectile; and this comparison, though rough (for the obliquity of the axis and the form of the point of the elongated shot are not considered), is sufficiently accurate to account for the results obtained in practice.

Range increases with the length of shot.—It will hence be obvious that as an elongated projectile is lengthened (its weight remaining the same), so the diameter being necessarily decreased, a longer range will be obtained.

Long ranges due to the introduction of elongated projectiles.—The long ranges of projectiles fired from rifled arms now in use are due to the substitution of elongated for spherical projectiles. The initial velocities of the former are usually much lower than those of balls fired from smooth-bored arms; but as, in consequence of their peculiar form, elongated projectiles offer so much less surface to the resistance of the air, their velocities are maintained for a longer time than those of balls. That this is practically the case, may be seen by an inspection of the following range table:

TABLE 1.

Gun.	Projectile.	Initial Velocity	Elevation.					
			1°	2°	3°	4°	5°	6°
		Feet.	Yards.	Yards.	Yards.	Yards.	Yards.	Yards.
12-Pr. Smooth-bore .	Ball	1,769	700	1,000	1,200	1,400	1,600	1,800
„ Rifled . . .	Elongated	1,184	680	1,015	1,335	1,655	1,956	2,218
32-Pr. Smooth-bore .	Ball	1,690	790	1,160	1,460	1,690	1,910	2,110
40-Pr. Rifled . . .	Elongated	1,164	720	1,100	1,455	1,810	2,160	2,505

That an elongated projectile maintains, up to a long range, a much higher velocity than a ball fired with even a higher initial velocity, will perhaps be made more apparent by the following comparison of the respective "initial" and "final" velocities of a ball and an elongated shell:—

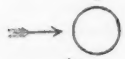
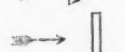
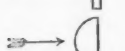
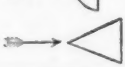
TABLE 2.

Projectile.	Range.	Time of Flight.	Initial Velocity.	Mean Velocity.	Final Velocity.
	Yards.	Seconds.	Feet.	Feet.	Feet.
40lb. Segment Shell (Elongated)	2,000	6·25	1,164	960	756
68lb Solid Shot (Ball) . . .	2,000	6·25	1,579	960	341

Now this case is favourable to the ball, the total weight and specific gravity of which are both greater than those of the shell, but it is nevertheless evident that the velocity of the ball has rapidly decreased in comparison to that of the elongated shell.*

Effect of Form upon Range.—The retardation of a projectile is influenced by the form of both its fore and hind part, but especially by the shape of the former. The following table† of resistances to bodies of different forms, moving with low velocities of 10 feet per second, is constructed from the results of Dr. Hutton's experiments with the "whirling machine" invented by Robins.

TABLE 3.

FORM OF THE BODIES.	Experimental Resistance.	Theoretical Resistance.
1. Hemisphere, convex side foremost .	119	144
 2. Sphere	124	144
3. Cone, angle with the axis 25° 42′ .	126	53
 4. Disc	285	288
 5. Hemisphere, flat side foremost . .	288	288
 6. Cone, base foremost	291	288

The experimental resistances to 2 and 3 are about the same, notwithstanding the sharp point of the latter. The resistances to the three last, which theoretically ought to be double of the two first resistances, are experimentally much more, in fact 2½ times as much.‡

The next table is taken from Piobert's "Cours d'Artillerie," and contains the results of experiments made by Borda in the last century, with velocities of 3 to 25 feet a second.

* A long range is taken so that an error in time of flight may be small.

† Extracted from Capt. (now Lieut.-Col.) Boxer's Treatise on Artillery, page 152, art. 299.

‡ Dr. Hutton's remarks on these experiments will be found in his 36th Tract, page 190, vol. iii.

TABLE 4.

Form of the Base of Prisms.	Experimental Resistance.	Theoretical Resistance.
1. Triangle, base foremost . . .	100	100
2. Triangle, apex foremost . . .	52	25
3. Demi-ellipse	43	50
4. Ogival	39	41

From this table it appears that the ogival form experienced the least resistance.

Forms of Elongated Projectiles used.—With high velocities the results might perhaps differ considerably from the above, and experiments carefully executed can alone enable us to determine the form of projectile which will attain the greatest range with a given initial velocity. One of three different forms is generally employed for the head of an elongated projectile. The figures below represent sections of these three forms.

Fig. 1. Fig. 2. Fig. 3.

Fig. 1 is the section of a "cone." Fig. 2 is the section of a "conoid," or a figure generated by the revolution of a conic section about its axis. Fig. 3 is the section of a pointed arch, which is termed by the French "ogival." The last is most probably the best form, as the one which experiences the least resistance from the air.

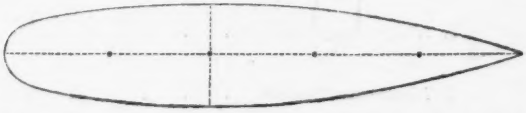
Sir Isaac Newton in his Principia gives a form of body which would, in passing through a fluid, experience less resistance than a body of any other shape.

Fig. 4.—Newton's Form.

This form, it will be seen, is very similar to the ogival.

Piobert says that the form fig. 5 will experience the least resistance from the air. Its length is five times its greatest diameter, and its largest section is placed at $\frac{2}{3}$ of the length from the hind part.

Fig. 5.—Piobert's Form.



The shape of some of Mr. Whitworth's projectiles approach more nearly to this form than those of any elongated projectiles hitherto used.

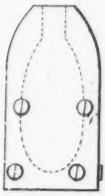
Circumstances affecting the Accuracy of Fire of Elongated Projectiles.—The circumstances which affect the accuracy of fire with elongated projectiles must now be considered. Elongated projectiles cannot be used with advantage if fired from smooth-bored guns, for it is found in practice that at a short distance they turn over in their flight, and are therefore useless. This arises from the tendency of such bodies to rotate round their shortest axis, if a force be impressed upon them which does not pass through their centres of gravity. The force which turns them over is the resultant of the air's resistance, which acts below the point of the shot at all angles of elevation given in practice. In vacuo an elongated shot would require no rotation.

Influence of the Position of the Centre of Gravity upon the Motion of a Shot.—The position of the centre of gravity of an elongated shot influences the motion of the projectile. If it be placed very far forward, the shot, unless it have a very high velocity of rotation, will proceed with its longer axis coinciding very nearly with the tangent to the trajectory; but this position is unfavourable as regards accuracy, for the wind has great disturbing effect and causes uncertain deviations. If the centre of gravity be placed far back, then a very high velocity of rotation is indispensable to prevent the shot from turning over; and this high velocity of rotation is objectionable, for the following reasons:—The strain upon the metal of the gun will be very great, for the charge must be large, and the grooves will require a sharp turn, much resistance being thereby caused to the motion of the projectile; the shot, after grazing, will deflect considerably; and, should the projectile be a sharpened or segment shell, the pieces would spread laterally to too great a distance to be effective. However, the rapid rotatory motion of the projectile is favourable to penetration, and, perhaps, to range.

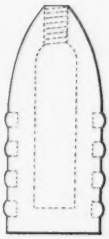
Effect of the Resistance of the Air upon a rotating elongated Shot moving with a high Velocity.—In almost all elongated projectiles in use the centre of gravity is situated in or very near the centre of the figure, and I shall therefore, in the following explanation of the effect produced by the resistance of the air upon the motion of an elongated projectile rotating rapidly, assume that the centre of gravity is in the centre of the figure; and also, that the shot has a "right-handed" rotation, *i. e.*, that the upper part turns from left to right with reference to an observer behind the gun, this being the rotation generally given.

PROJECTILES FOR RIFLED ORDNANCE.

Armstrong.



French.



Prussian.

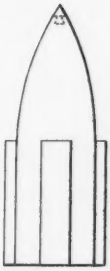
Whitworth.

BULLETS FOR SMALL ARMS.

Minié.

Enfield.

Whitworth.



Jacob.

J.R.Jobbins

When an elongated shot is fired from a rifled gun, it leaves the bore rotating rapidly round its longer axis; and if the initial velocity were very low, the projectile experiencing but slight resistance from the air, the longer axis would remain (as in vacuo) during flight parallel, or nearly so, to its primary direction. This I will show by experiment.

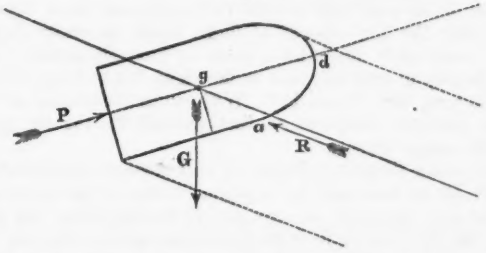
Before proceeding, it will be as well as well to remind you of the enormous force exerted by the resistance of the air upon a projectile moving with a high velocity. At a velocity of 1200 feet a second, which is about the initial velocity of the Armstrong projectiles,

A 100 lb.	shot will be resisted by a force of		432 lbs.
40 lb.	,,	,,	203 lbs.
20 lb.	,,	,,	127 lbs.
12 lb.	,,	,,	79 lbs.

The effect of the pressure of the air upon an elongated projectile fired from a rifled gun may be observed by means of a gyroscope provided with a small elongated shot, and for this purpose, the shot having no motion of translation, a strong blast of air must be directed upon it, so as to cause similar effects to those which would be produced, if the projectile were passing with a high velocity through the atmosphere. It will be found that the effects produced will vary with the form of the point of the shot; therefore, in the first place, the effect upon a conoidal head will be considered, and secondly that upon a flat head.

Cylindro-conoidal Projectiles.—As before explained, the resultant of the resistance of the air will act upon a point in front of the centre of gravity and below the longer axis, at all angles of elevation given in practical gunnery. This may be at once perceived by referring to fig. 6.

Fig. 6.



P represents the direction of the force of projection, *G* that of gravity, while it is obvious that *R*, the resultant of the resistance of the air, must be parallel to the trajectory described by *g*, the centre of gravity of the shot. The pressure *R* must always act in front of *g*, unless the centre of gravity is very far forward.

Experiment with Pressure.—If fig. 6 represent the elongated projectile of the gyroscope, it will be found that a pressure, *R*, exerted anywhere between *a* and *d*, will raise, unless the force acts perpendicular to the surface and through the centre of gravity, the point *d* when the projectile

is not rotating. Should, however, a rapid rotatory motion be given to the shot, the effect will be very different; for the point *D* will move round in a circle, the centre of gravity of the shot remaining at rest, so that a conical motion will be produced. Now, if the rotation is right-handed, the circle will be described from right to left, the line of pressure, *R*, passing through the centre of the circle. This movement of the point in a circle *b*, *b*, *b*, is shown in fig. 7.

Fig. 7.

The spectator, in this figure, is supposed to be in front of the shot looking at the point, and therefore his left will be the shot's right.

Experiment with the Blast of Air.—If I now direct the blast of air upon the projectile of the gyroscope first at rest, and then when rotating, similar effects will be produced. Should the rotation be left-handed, the circle will be described in the opposite direction, or from left to right.

Application of the Principle to the Case of an Elongated Shot fired from a Gun.—Now if this principle be applied to the case of an elongated shot fired from a gun, it must be evident that the longer axis will not remain during flight parallel to its primary direction, when the velocity is high enough to create considerable resistance; but the point of the shot will first move to the right, then downwards, and so on, describing a portion of the circle, the continuance of the motion depending upon the time of flight and the velocity maintained. As the velocity becomes low the circular motion of the point will become very slight and then cease; but in practice during the few seconds of flight which generally elapse, as the velocity is pretty high throughout, there is probably sufficient time and pressure, not only to turn the point to the right, but to bring it down on to the trajectory, or even below it.* With an artificial blast a very slight pressure is obtained compared to that exerted by the air upon a shot moving with a high velocity.

Long Axis not a Tangent to Trajectory with ordinary Elongated Shot.—It is very difficult to ascertain by experiment the actual position of the longer axis of a projectile at any part of the trajectory, but there is no doubt that the axis cannot, as it has sometimes been erroneously supposed, remain a tangent to the trajectory, unless the centre of gravity be very far forwards, and the velocity of rotation be low.

That the axis of an elongated shot inclines during the flight to the right may be frequently seen from the direction of the grazes; and it is almost invariably found in practice, up to 8° or 10° of elevation, that the effect produced upon an object is similar to what would occur, if the shot struck point first, which can only be accounted for by the drooping of the point. This drooping is of importance, for, did the axis remain

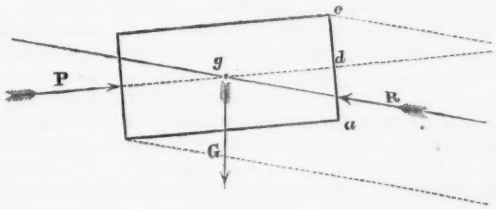
* Pointed out by Professor Magnus, in his paper on the "Deviation of Projectiles."

parallel during flight to its primary direction, the projectile would most probably, when fired at a high angle, on striking the object turn up against it lengthways, and therefore produce but little effect. This has not, however, been found to take place at the experiments hitherto made, but on the contrary, the penetrations of elongated shot are always remarkably great; and there is little fear of the shot turning up against an object unless the velocity both of translation and rotation be very low, and the angle of fire very high.

Deviation of Elongated Projectiles.—It is found in practice that elongated projectiles, fired from rifled ordnance giving a right-handed rotation invariably deviate to the right; and in the few cases tried with guns giving a left-handed rotation to the left. This peculiar deviation of projectiles fired from rifled pieces is termed by the French "derivation," and can only be accounted for by the turning of the point during flight, as already explained, to the right, the air acting therefore more on one side than on the other.* It has been supposed that the pressure of the air underneath the shot causes this deviation, the shot rolling to the right, in consequence of the great pressure below, compared to that above; but it must be remembered, that with shot fired at low angles, and with high velocities, the pressures above and below will not differ very much. There will, of course, be a more or less complete vacuum behind the shot. The "rolling" effect adds doubtless to the deflection of a conoidal pointed shot.

Effect upon a Flat Head.—The effect produced on a cylindrical or flat-headed projectile will now be noticed. A pressure exerted upon the head and below the longer axis, as R in fig. 8, will when the projectile is not

Fig. 8.



rotating cause the head to droop, or will produce an effect similar to a downward pressure acting at c; just the opposite to what was before observed with a conoidal-pointed projectile. It would therefore appear, that the fore-part of a flat-headed projectile fired with a right-handed rotation, would, in consequence of the resistance of the air, not turn to the right but to the left, and this is found to be the case if a blast of air is directed upon a projectile of this form in a gyroscope, the axis of the centre of the current of air being directed upon a point a little below *d* fig. 8. It has been asserted that flat-headed projectiles fired with a

* See Magnus' paper on the "Deviation of Projectiles."

right-handed rotation deflect to the left, which may be expected, from the turning of the front of the shot towards the left during flight.*

Circumstances upon which Penetration depends.—The penetration of a projectile depends upon a variety of circumstances, such as its velocity at the moment of impact, its density, diameter, nature of the object struck, and the relative position of this latter with regard to the trajectory.

The "work done" upon the material into which projectiles of similar form are fired may be considered proportional to $w\,v^2$, where w = weight of projectile v = velocity at the moment of impact.

Penetration of Elongated Projectiles.

The penetration of an elongated projectile is greater than that of a spherical shot of equal diameter and of similar density if they are both fired with equal initial velocities and at the same angle of elevation; for, the weight of the former being so much greater than that of the spherical shot, its penetration will be greater, and also it will be less retarded and have a greater final velocity, the penetrations being as the squares of their respective velocities at the moment of striking. In general, however, an elongated projectile is fired with a lower initial velocity than a ball of equal weight from a smooth-bored gun, and, therefore, at a short distance the latter will most probably produce more effect as regards penetration than the former; but as the range is increased so will the penetrating power of the elongated projectile be greater compared with that of the ball, for the former will maintain a high velocity much longer than the ball. It is only at very short ranges—such as 500 or 600 yards—that the fire of a smooth-bored gun is sufficiently accurate to allow of a comparison of its results with those obtained from practice with a rifled gun; beyond such ranges the accuracy of a smooth-bored gun cannot be depended upon, and the total effect produced by a number of balls upon an object would most likely be inconsiderable. But with a rifled gun the blows of its elongated projectiles can be repeated on the same part of the object at much longer ranges, and a wall or side of a ship could, therefore, be battered with effect at ranges where balls would be practically useless. The pointed form of the fore-part of the elongated projectile assists no doubt in increasing its penetration into substances such as earth or sand. But it is found that for penetrating very hard substances of comparatively small thickness—such as wrought-iron plates—a flat-headed projectile gives the best results, punching a hole completely through a plate which would defy the more pointed projectile. Some small projectiles of cylindrical form lately tried against iron plates gave very excellent results, punching clean holes of the same diameter as the projectile. Flat-headed projectiles have no advantage if fired against slabs of iron; but it has been found that the fore-part of a projectile of such form spreads out after making only a slight indentation. In order to obtain penetration into an iron slab or plate, the thickness of the metal must bear a certain

* Experiment has proved that flat-head shot having a right-handed rotation deflect to the left. See Appendix B. in an "Essay on the Motion of Projectiles fired from Rifled Arms," by Major Owen, R.A.

proportion to the momentum of the projectile, and, as the velocity of the latter is higher, its diameter and weight remaining the same, so will its penetrating power be greatly increased; in fact, increase of velocity will be of more advantage than greater weight as regards mere penetration. There is no doubt but that the rotatory motion of a projectile fired from a rifled gun greatly increases the penetration.

Principles derived from the preceding Remarks.

It will now be desirable to state a few general principles derived from the preceding remarks, and which may be capable of practical application.

1. *Accuracy of Fire dependent upon Velocity of Rotation.*—The "accuracy of fire" depends upon the velocity of rotation imparted to the projectile; the more rapid this velocity the more accurate will be the practice. As, however, a high velocity of rotation is objectionable for several practical reasons, it will generally be sufficient to give such velocity of rotation as shall be maintained throughout the flight of the projectile up to the longest range required.

It may be observed here that the velocity of rotation depends upon the turn of the grooves and the initial velocity of the shot.

Initial velocity in feet divided by number of feet in which one turn is made equals number of revolutions made by the shot in a second.

The charge must not be substituted, as is often done, for the initial velocity; for projectiles of similar form and equal weight, if fired with equal charges from guns rifled on different systems, will most probably have very different initial velocities. The electro-ballistic apparatus must in future be used in all cases when it shall be requisite to compare accurately the respective powers of different guns.

Heavy projectiles require less velocity of rotation.—The greater the specific gravity of a shot the less velocity of rotation will it require, for this velocity will be less diminished during flight by the resistance of the air.

Long projectiles require a high velocity of rotation.—The longer the projectile (the weight remaining constant) the greater must be the velocity of rotation given to it, in consequence of its greater tendency to turn over in flight.

2. *Accuracy of fire dependent upon stability of axis of rotation.*—In order to secure accuracy of fire it is essential that the axis of the projectile should correspond with that of the bore of the piece, for otherwise the axis of rotation will be variable, and the deflection of the projectile uncertain. Should the axis of the shot on leaving the bore be unsteady, the projectile will have the "wabbling" motion so frequently observed in experimental practice. It is therefore indispensable that the "bearings" of the projectile should extend along the cylindrical part, or should be very near the centre of the shot, for if they be either too far forward or behind, unsteady motion must result from the axis of the projectile being inclined to that of the bore.

When the whole length of the cylindrical part of the shot bears against the grooves, the projectile fitting the bore tightly, as is the case with almost all rifled small arms having leaden bullets, with breech-loading

ordnance, like the Armstrong or Prussian guns, or with the Armstrong "shunt" gun, L. Thomas's rifled gun, &c., the axis of the bore and shot must coincide.

When there is any windage, as in the case of all muzzle-loading rifled pieces with hard projectiles having projections or buttons, there must be a slightly oblique movement of the axis of the projectile; but still, if the bearings are over the centre of the shot, or there are two sets, one round the fore part, and the other round the hind part, as in the French elongated shot, the axis of the projectile will no doubt on leaving the bore be tolerably steady. With the Whitworth rifled cannon, the projectile being made to fit the bore so accurately, and there being such a very trifling amount of windage, the axis of the shot is practically stable on leaving the bore.

Other cases might be stated, and the results of practice shown to prove that the above principle is correct, and that a violation of it, by placing the bearings at random and in the wrong position, only results in giving an unsteady motion to the shot, thereby causing inaccurate shooting.

3. *Influence of Initial Velocity and Form of Shot upon Range.*—The range of a projectile fired from a gun depends chiefly, where the ground is level, upon the initial velocity, the form of the shot, the angle of elevation of the piece, and the height of the latter above the plane. It will be unnecessary to make any remarks here on the two last circumstances. The range of a shot increases in a much lower ratio than the initial velocity, and velocities of over 1,344 feet per second (or the velocity with which air can rush into a vacuum) are quickly reduced. When only moderately long ranges are required from ordnance—up to 2,000 or even 3,000 yards—it is found that with elongated projectiles an initial velocity of about 1,200 feet a second gives very satisfactory results. This being the case, it would not appear desirable to require a higher initial velocity, except for particular purposes, as for penetrating metal plates or slabs. With small arms long ranges are of little practical utility; still, as it is desirable to have as flat a trajectory as possible at all ranges, a higher velocity than 1,200 feet can be given with advantage, especially as there is no difficulty in giving the barrel of a small arm the requisite strength for a large charge. The ogival form of head most probably experiences less resistance from the air than either the conical or conoidal, and therefore it is the best of the three as regards range; it is also probable that tapering off a projectile behind increases its range.

It has been shown that the range increases with the length of a projectile. But too great length must not be given to a shot, for it is found that the wind exercises a considerable disturbing effect on very long projectiles, causing the practice to be uncertain both in range and deflection, according to the direction in which the wind is blowing. Another objection is that very long projectiles require, as before explained, a very rapid rotatory motion.

The length of projectiles for rifled ordnance is generally from 2 to 2½ calibres, but bullets for small arms are sometimes 3 calibres long.

4. *Penetration chiefly Dependant upon a High Final Velocity, and upon the Form of the Shot.*—In order to obtain great penetration, a high final velocity is far more advantageous than great weight; and the form

of a shot must be adapted to the nature of the material fired at: if the latter be soft, it is better to have a pointed head; if hard, a rounded point; but when hard metal plates are fired at, a flat head has been found to produce the greatest effect. Velocity of rotation increases penetration.

5. *Best Position for the Centre of Gravity of an Elongated Shot.*—Many opinions are held with respect to the best position for the centre of gravity of an elongated projectile; but, on the whole, it would appear that it should be situated very near, or actually in the centre of the figure, for the effect of a wind will then be uniformly distributed over the whole length, and a moderate velocity of rotation will give stability of axis.

Advantages Obtained by the Employment of Elongated instead of Spherical Projectiles.

I shall now proceed to point out the advantages gained by the substitution of elongated for spherical projectiles.

Advantages.—From what has been said it must be evident that the following are the chief advantages:—

1st. Very great accuracy of fire.

2nd. Long range.

3rd. Great penetration.

4th. Small charge, and therefore much saving of powder.

Accuracy.—It has been shown that, except for very short ranges, elongated projectiles are fired for equal ranges at a less angle of elevation than balls of similar weight (see Table 1); this being the case, the chance of striking an object at a given distance must be evidently greater with an elongated shot in proportion as its angle of elevation is less than that at which the ball must be thrown.

It has also been explained that under favourable circumstances the deflection of an elongated shot fired from a rifled gun is constant for a given range, and always occurs to the same side, and can therefore be allowed for in "laying."

As good practice can now be made at 3,000 yards with rifled guns as could formerly have been obtained at a range of 1,500 yards with smooth-bored ordnance, and with projectiles from the former a 9-foot target may, when 1,000 or 1,100 yards distant from the gun, be struck nearly every time.

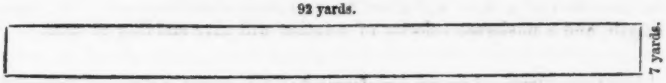
Accuracy of Fire of Guns compared by probable Rectangles.—In order to ascertain the relative precision of fire of different ordnance in a more satisfactory way than can be done by a mere inspection of tables of practice, Captain Noble, R.A. proposed to apply the "theory of probabilities" to the calculation of an area for each particular gun, so that a comparison of the respective areas would at once show the relative accuracy of fire of several guns under trial.* The area, being derived from the results of practice with the gun, represents a space within which there would be an equal chance of any shot fired from the gun striking; or, if a given number of shot were fired, half of the number might be expected to fall within the area.

* Occasional Papers of R. A. Institution, vol. i. page 173.

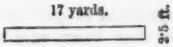
The following areas or "probable rectangles," as they are called, were calculated by Captain Noble from the results of practice at Shoeburyness :—

DIAGRAMS OF COMPARATIVE ERROR.

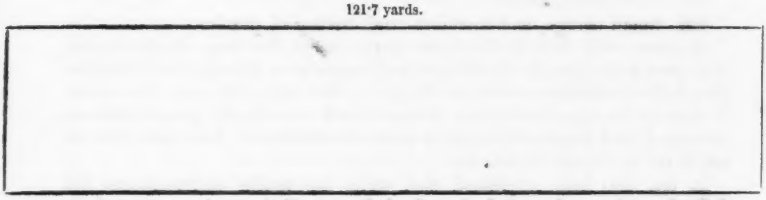
Service 18-Pr. Range 800 yards.



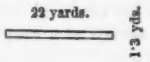
Armstrong 18-Pr. Range 800 yards.



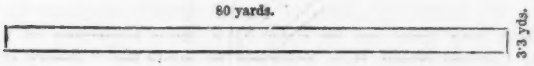
Service 18-Pr. Range 1,760 yards.



Armstrong 12-Pr. Range 1,760 yards.



Armstrong 12-Pr. Range 3,000 yards.



These diagrams show plainly the immense superiority of the rifled guns in precision of fire.

Circumstances favourable to Accurate Shooting.—In order, however, to secure this accuracy of fire, supposing the powder to be of uniform quality, the gun must be fired under the following favourable circumstances, viz.:—

1st. The gun-carriage must stand upon a level and sound platform.

2nd. The distance of the object must be known.

3rd. There must be sufficient time to allow of the gun being "laid" with care.

4th. The air must be still, there being little or no wind.

Deflection after Grazing.—Projectiles fired from rifled guns deviate very considerably after grazing, the deflection varying with the velocity of rotation, the nature of the ground, &c.; and, therefore, in certain cases, as, for instance, in firing at an object of little breadth, this deflection will evidently impair the accuracy of fire, for if a shot strikes short it will most probably ricochet wide of the object. Shell fire has now, however, become so general for almost all artillery purposes, that the deflection of elongated projectiles after grazing is comparatively unimportant.

Very long Ranges, and Circumstances which limit Ranges in Practice.—It is necessary to make a few remarks on very long ranges, and on the practical limits to the ranges of projectiles intended for general service. The following ranges have been obtained from rifled ordnance:—

A 32 lb. shot fired from an Armstrong gun at 33° of elevation ranged 9,153 yards.

A 3 lb. shot fired from a Whitworth gun at 35° of elevation ranged 9,688 yards.

A 175 lb. shot fired from a gun of Mr. L. Thomas at 37½° of elevation ranged 10,075 yards.

All these ranges being obtained at very high angles, over 30°, the "angles of descent" of the projectiles must have been very great, so that the chance of striking an object in this manner would not certainly be worth the powder expended.

The difficulty of judging the distance, of laying a gun upon an object at a long range, and of observing the effect of the fire, also the disturbing influence of the wind during a long time of flight, will confine the ranges of projectiles used for military purposes within 2,000 yards, or perhaps in special cases, when firing at masses of troops, ships, buildings, &c. to 3,000 yards.

It is not to be denied that a random shot may now and then do a great deal of damage at much longer ranges, but artillery fire must not depend on chance, and should therefore be confined to ranges at which tolerably certain effects can be produced.

Saving in Powder.—The charges with which smooth-bored ordnance are generally fired vary from $\frac{1}{6}$ to $\frac{1}{3}$ the weight of the projectile, but rifled ordnance have charges of only from $\frac{1}{10}$ to $\frac{1}{6}$ the weight of the projectile.

Power of Artillery increased.—Combining these several advantages, we find, that by the employment of rifled ordnance with elongated projectiles, the effective power of artillery has been very much increased, and that this increase of power has been obtained with a great saving of time, projectiles, and powder.

The Employment of Rifled Field Artillery.

It will now be necessary to consider the influence of this increased power upon military operations.

Projectile for Armstrong's 12-pounder Field-piece.—The 12-pounder

rifled field-guns (Armstrong) are supplied with only one kind of projectile called the segment shell, which can be used as a shot, shrapnel, or case. When intended for a shot, no fuze is used; for a shrapnel shell the fuze must be arranged so that the shell may burst, like a shrapnel, at a short distance before the object; and for case, the fuze is set to zero, so that the shell shall explode immediately after leaving the bore of the gun. That successful results can be obtained in practice with this shell has been fully established; and it is found that when used as a shrapnel the penetration of the segments is very great.

Comparison of Effects produced by Elongated and Spherical Projectiles respectively.—Now the final velocities of elongated projectiles being, as already shown, so much greater than those of round shot and shell, at all but very short ranges, the penetrating effects produced by elongated shot and shrapnel (or segment shells) must necessarily be very much greater, at ordinary or long ranges, than those caused by similar spherical projectiles. In the case of shrapnel fire this is of very great importance, for one of the chief defects of ordinary shrapnel practice from smooth-bored pieces is, that the penetrations of the bullets are generally very slight at ranges over 1,000 yards.

The ammunition of our field guns has certainly been simplified by the introduction of a single projectile, but this shell would be useless in many situations where the common shell* of the 24-pounder howitzer might do considerable execution; and at close quarters the former, depending for its action upon the proper adjustment of a fuze, would be very inferior to the ordinary case shot, especially as two of these can be fired together.

Simplification of Matériel.—Our matériel has in some respects been simplified by the introduction of rifled (Armstrong) field guns† of only one calibre, but this simplification was adopted in the French artillery, by the Emperor Napoleon,‡ long before rifled ordnance were used.

Peculiar Circumstances affecting the Accuracy of Fire of Field Pieces.—It is very difficult to obtain precision of fire in the field for the following reasons:—The gun-carriage rarely stands on even ground, or on exactly the same ground twice. The difficulty of judging distances and of laying the gun is very great, for the objects are generally moveable, and are frequently obscured by dust and smoke. Haste and carelessness in laying the piece are often unadvoidable when uncovered guns are served under a heavy fire.

Results which can be practically attained with Rifled Field Pieces.—We must not therefore expect the astounding effects often said to be obtained on targets at experimental practice, but must be content with the attainment of the practical advantages that have been pointed out. At the commencement of an action, or in annoying reserves or troops at a distance of even 2,000 yards, very great effects may doubtless be produced with the projectiles of rifled field guns. At ranges of 1,000 or 1,500

* The 24 lb. shell contains 13 oz. of powder; the 12 lb. segment shell only 31 drs. just sufficient to open it.

† A light 12-pounder gun of 6 cwt., carrying a 9 lb. projectile, has lately been introduced for the Horse Artillery.

‡ When President.

yards, they may be confidently expected to do fearful execution among compact bodies of troops, and to dismount an enemy's field guns. At very short ranges up to 300 yards, the fire of smooth-bored field-pieces will do as much, if not more execution, than that of rifled guns not adapted for case shot.

It has been sometimes asserted that the increased power of rifled small arms will in future enable them quickly to silence batteries of artillery; but every one who has had practical experience in warfare knows well that riflemen, unless completely covered, will do but little harm, and often even disperse when plied with shell from smooth-bored pieces. So that rifled guns provided with shrapnel or segment shells have little to fear under ordinary circumstances from the fire of small arms. In certain cases—as when men are posted in buildings or when firing from behind parapets—riflemen can undisturbed take deliberate aim, and their fire will no doubt be very harassing at considerable ranges.

The Superiority of Rifled Pieces for Guns of Position.—The superiority of rifled over smooth-bored position artillery will be very great; for, as the pieces intended for position guns are generally used at long ranges, they can be carefully laid—they may sometimes be provided with platforms, and in certain cases with small parapets for cover. The rifled 20-pounder, which is intended for a gun of position, when compared with the smooth-bored 18-pounder, has, besides the greater range, accuracy, and penetration of its projectiles, the following advantages: The weight of the rifled gun is not half as much as that of the smooth-bored piece;* the carriage of the former is very much lighter than that of the latter; the projectiles of the rifled piece are the most powerful, and are fired with only half the charge used for the shot and shell of the smooth-bored gun.

The total weights, gun and carriage, of the 32-pounder howitzer and of the 20-pound rifled gun are about the same; that of the howitzer being rather the lightest. The projectiles of the howitzer are rather more formidable in themselves than those of the rifled gun—for the common shell of a 32-pounder howitzer weighs 24¼ pounds, and has a burster of 1 pound 2 ounces; the common shell of 20-pound (rifled) gun weighs 21 pounds, and has a burster of 1 pound. But the effective power of the rifled gun is very much greater than that of the howitzer, on account of the inaccuracy, short ranges, and low velocities of the shells of the latter. The 18-pounder, weighing with its carriage 74 cwt., is a most unwieldly affair, and could never, unless the roads were good, keep up with an army on the march.

Rifled Artillery for Siege and Garrison Service.

Guns and Ammunition for Siege Artillery.—The smooth-bored and rifled pieces, with their respective projectiles, used as siege guns in our service may be compared by an inspection of the following table.—

* Because the former is made of wrought instead of cast iron.

TABLE 5.—SIEGE PIECES.

SMOOTH-BORED PIECES.

Nature of Gun.	Weight of Gun.	Weight of Carriage.	Charge.	Weight of Shot.	Common Shell.	
					Weight.	Burster.
	Cwt.	Cwt.	lbs.	lbs.	lbs. oz.	lbs. oz.
8-inch . .	52	39¼	8	46 Hollow	49 10	2 4
32-pounder .	50	38	8	32 Solid	24 5	1 2
24-pounder .	50	37½	8	24 „	17 8	0 13
RIFLED GUN.						
40-pounder .	32	42½	5	41 0	41 0	2 8

It may be seen that the rifled gun has the following advantages:—The gun is lighter than either of the others, and the total weight of gun and carriage is also the lightest of the four; this is of great importance, for the transport of heavy ordnance is always difficult. The charge of the rifled gun is much less than that necessary for the smooth-bored pieces, and the shell contains more powder than the others. The hollow shot of the 8-inch gun is rather heavier than the solid shot of the rifled piece, but the latter would, at all but very short ranges, have greater velocity, and would do the greatest amount of work ($w v^2$) upon a revetment.

The smooth-bored pieces in the table are also supplied with shrapnel, case, and grape, and the rifled gun with segment shells; so that, provided the latter can be depended upon at close quarters (in sorties, &c.), which it is said they can be, a great simplification of ammunition will have been made without any sacrifice of usefulness.

Circumstances favourable to Accuracy of Fire in a Siege.—In a siege, except during a very rapid bombardment, there is plenty of time to lay the guns with care, and as the objects are generally stationary, and the gun-carriages stand on platforms, great precision of fire may doubtless be obtained with projectiles fired from rifled guns. This precision is of the very greatest importance, for in a siege the objects to be struck are often of small extent; for instance, when firing through the embrasures of the fortress at the guns inside them, or in throwing a number of projectiles at exactly the same portion of a wall or parapet.

Power of Siege Artillery greatly increased.—It must appear then from what has been said that the requisite destructive effects upon the ordnance, revetments, &c., of a fortress can now be produced with the projectiles of rifled ordnance in a much shorter time, with a less quantity of ammunition, and at a far longer range than formerly. That this is practically the

case has been proved in a great measure by experiments in England and on the Continent.

Experiments in England.—An account of some experiments carried on in this country to test the respective powers of rifled and smooth-bored guns in breaching masonry at a long range, viz., 1,032 yards, is given in the Proceedings of the Royal Artillery Institution. With regard to these experiments, the Ordnance Select Committee made in their Report the following remarks:—"It appears that, irrespectively of the superior concentration of the fire of the rifled guns, and its consequently greater effect, they actually performed half as much work again as the smooth-bored guns, with the diminished expenditure of iron and gunpowder noticed in a previous paragraph." Again,—"The precision with which the guns could be directed upon any point it was intended to strike gave them advantages with which no smooth-bored ordnance firing from such a distance could compete; and the same circumstances would have rendered it almost impossible to retrench or defend the breach, for the fire might have been continued with perfect safety to the assaulting columns until they were within a very few yards of it, sweeping away all obstacles as fast as they could be laid, and without the slightest interruption from the musketry of the defenders, the battery being quite out of their range."

Prussian Experiments.—An abstract of the Prussian experiments at Julich in 1860 is given in the "Professional Papers" of the corps of Royal Engineers. The conclusions drawn from these experiments were: "That rifled ordnance can be employed advantageously for firing at a covered object, not visible from the battery, at longer ranges than smooth-bored pieces; that reduced charges may be used successfully with projectiles from rifled guns; that the effect of the shells from these pieces is so great that no other kinds of ordnance are required for breaching; that 13-pound shells fired from rifled guns are sufficient to breach quickly a good wall of moderate strength; that 27-pound shells from the same pieces can destroy in a short time embrasures in the strongest masonry; and that 57-pound shells from rifled guns can breach, with a comparatively small expenditure of ammunition, the strongest masonry."

The 40-pound Armstrong gun fires a common shell, which contains 8 ounces more powder than the above 57-pound shell. The angle at which the shells were fired to breach a block-house that could not be seen from the battery was about $6\frac{1}{4}°$; so that the angle of descent of the shells would be about $8\frac{1}{4}°$.

Results in Ordinary Practice.—It is perhaps unnecessary to remark that results equal to the above cannot be expected in actual warfare where conditions are less favourable to precision of fire; but the great superiority of rifled over smooth-bored ordnance for breaching can hardly be doubted. As before observed, the point of an elongated projectile droops during flight, unless the velocity be very low; so that more penetration can most probably be always obtained with elongated than with spherical projectiles fired under similar circumstances.

Ricochet.—Elongated shot, on account of their rotatory motion causing them to deflect after grazing, are certainly not so well adapted for "ricochet" fire as the balls of the smooth-bored pieces. But no artillery officer would, I should imagine, ever resort to firing shot with very low

velocities, so that they may make a couple of bounds in a work, when he can fire these shot as shells, or obtain common shells, which may be exploded after clearing the enemy's parapet. Those who have had much gun practice will, I think, agree with me that it is far better to rely upon the explosion of a shell than on the bound of a shot moving very slowly.

Rifled Ordnance for Garrison Artillery.—In estimating the probable effect of the employment of rifled ordnance on siege operations, we must remember that these guns will greatly increase the means of defence. It is very easy to talk of breaching and enfilading works; but engineers do not generally allow these things to be done without at least a great deal of preliminary work. The effective ranges of guns being increased, lines of defence will be lengthened, revetments will be covered, and every possible advantage taken of the nature of ground to nullify the effects of fire.

Those who served in the first bombardment at Sebastopol must remember that a considerable number of guns were soon dismounted and men killed even by the fire of smooth-bored guns at ranges of 1,600 and 1,700 yards; and it will doubtless be a very difficult thing to establish batteries under a heavy fire of good rifled ordnance. The fire of large segment or shrapnell shells will be the most effectual way of disturbing working parties.

Being an artillery officer, I do not presume to give advice as to the best way of protecting revetments, but I may perhaps be allowed to suggest that they should be covered as much as possible, and that portable iron slabs of requisite thickness, which like Thornycroft's could be easily put together, might be kept in the fortress, and placed when necessary before the part of the masonry attacked.* Iron being so expensive can only be used in comparatively small quantities, and if attached permanently to works here and there the besieger could often avoid the parts strengthened; but if the iron be removable it need not be placed before the point to be breached is known.

Rifled Ordnance in Coast Batteries.—The employment of rifled ordnance for naval warfare is beyond the limits of my subject, and I will therefore only remark that, as regards precision of fire, land batteries possess several advantages over ships, for the gun carriages in the former stand on sound level platforms, while those on board ship rest on an unstable surface, which must greatly interfere with the accuracy of the practice; the ranges would most probably be known to the men in the battery, but not to those on the ship; also that shells produce little effect on parapets or massive walls, compared to the terrible destruction created by their explosion inside a vessel. Now, however, that vessels are being plated with iron, they will be comparatively invulnerable, at least to shells; but it is to be hoped that the safe and rapid movement of our vessels will not be sacrificed to mere security from the effects of fire. An extensive series of experiments have lately been carried on to ascertain the effects produced by projectiles fired from rifled ordnance upon wrought iron of different kinds, but the results have not yet been published.

* We shall thus be following the example of the Ancients, who used to let down bags of wool from the top of the wall to deaden the shock of the battering-ram.

Concluding Remarks.—Having now briefly considered the various parts of my subject, I will conclude by stating my opinion, that the increased power of rifled arms, both muskets and ordnance, will doubtless hasten military operations, on the field or in sieges, but that I see no reason for change in the employment of the three arms of the service, each being as necessary for its own peculiar work as it has ever been. It will now be necessary to move troops with more rapidity than formerly to avoid the destructive effects of fire; and for the same reason, men must not be kept in masses but in lines, even at considerable ranges. Troops must, however, eventually come to close quarters in an engagement, in an assault, or in any other operation, and the new arms will then be of no advantage to either party. Fortunately for us, British soldiers are possessed of the two most essential qualities of courage and coolness, useful alike in enabling them to remain steady under a heavy fire at long distances, or to make the best use of their weapons in the excitement of close quarters.

Friday, April 25th, 1862.

Lieut.-General W. T. KNOLLYS, Vice-President of the Council of Military Education, in the Chair.

MILITARY SKETCH OF THE PRESENT WAR IN AMERICA.

By Major F. MILLER, R.A., V.C.

THE interest which we naturally feel in the American war has been fed from day to day by the special correspondence of the leading journals, and the ordinary intelligence of daily or weekly papers. But those notices, valuable as they are for the preparation of regular narratives, are apt to confuse as much as they inform us, unless we have the opportunity to treat them as a study. They group together events widely separated from one another both in time and place; they include, in one short paragraph, intelligence from the Atlantic coast and the rivers of the West; they give one day flying reports which they contradict the next, and they republish the same incidents in a new form a month afterwards. When, therefore, I was asked to give a lecture on the subject, I felt that I might do some service in collating these scattered accounts, and in producing a connected sketch from their voluminous materials. Brief and incomplete as the result may be, it may yet lighten the labour of other students, or increase the interest of following the future operations, by rendering more clear those which are past.

I need hardly say that a lecture delivered in this room should be something more than a mere summary of facts. If it treats of military history, it should point out how far principles were vindicated by the results of observing or neglecting established rules, and how any new weapon or any new feature in the equipment of an army influenced its movements or affected its achievements. If this ideal is but little realized, I must, in this instance, beg your indulgence; I could only give an hour or two of the evening to my task, and it is far more laborious to hunt for facts through the extensive columns of daily papers than to study a subject when it is already arranged in books. Moreover, it is much more difficult to describe concisely half a dozen disconnected operations, without definite beginning, without unity of plan, and not yet ended, than to master a campaign directed by skilful commanders and executed by men well acquainted with their work.

This last difficulty will diminish as the war progresses, and there is a far higher interest connected with the present operations than with the desultory marches and petty skirmishes in the first months of the war. When once the men can be relied on for marches and manœuvres, when they are able to do what an army ought, there is no reason why the celebrated campaigns of the Old World should not be equalled in the New. America may yet produce generals of the highest order, but it is to be wished that she should refrain from giving them names in anticipation of their achievements.

My purpose being to touch upon such points only as might be developed into a military history, I pass over in silence the causes which led to the separation of the Southern and the Northern States. But we ought to bear in mind the time at which a rupture was seriously spoken of as not only possible but probable, because we may fairly presume that the military preparations, on one side at least, may be traced back to that date.

It was in the early part of November, 1860, when the success of the Republican party in the contest for electing a President was no longer doubtful, that excitement began to be shown; it gained strength when the result of the ballot was declared; and serious apprehensions began to be felt, which were soon to be fully realized. On the 13th December certain representatives from Southern States had a meeting at Washington, in which they declared that all hope of an honourable adjustment was extinguished, and that their only refuge lay in a prompt secession. Within a few days the declaration was reduced to practice. On the 19th December South Carolina took the lead, and resolved, by a unanimous vote, to withdraw from the Federal Constitution; Florida, Mississippi, Alabama, and Georgia followed her example early in January, and in all these States possession was taken of the forts and arsenals, which were generally left without any military force to protect them. Fort Pickens, near Pensacola, and Fort Sumter, at the entrance to Charleston harbour, escaped this fate from having small garrisons of regular troops. The surrender of the latter was officially demanded from President Buchanan by a Special Commissioner sent to Washington, and, of course, refused.

But, though not yielding in this point, the Government remained almost inactive. The President said that he refrained from sending any reinforcements to a threatened point lest they should be regarded as a menace of coercion, and thus furnish to the disaffected an excuse for an outbreak. Afterwards the Secretary of War announced that reinforcements would be sent to any post if they were demanded by the officer in charge, or if they seemed to be required for safety's sake. With this the people were content; New York quietly followed her commercial business, and Washington swarmed with place-hunters, anxious only about getting appointments under the new administration. The Seceders, on the other hand, declared their intention of seizing those forts which had hitherto escaped their grasp; they began to throw up batteries, and put guns in position, to enrol men, and prepare munitions of war; at Charleston, which had become the point of principal interest, an attack on Fort Sumter was daily expected.

Nearly two months passed in this manner. Major Anderson, the officer in command at Fort Sumter, demanded reinforcements, but the Cabinet,

not acting up to the Secretary's announcement, was divided in opinion about sending them, and reports were generally current that the place would be given up. The very day was mentioned. On the 23rd of March the garrison was to be withdrawn, and an opposite rumour that such a step was not quite decided was positively contradicted by a Washington paper.

With this chance of obtaining possession by fair means, the Confederate States, as they began to call themselves, were for the time content; there was too much risk connected with a war to hurry on without necessity such a step as must inevitably cause one. But on the 6th of April there came news that reinforcements of men and an armed squadron had been ordered to Charleston; then their activity broke into new life; 5,000 more men were called out, fresh batteries were thrown up, the supplies of food hitherto allowed to go from the town to the fort were immediately stopped, and Major Anderson was summoned to surrender the place.

On receiving his refusal the attack was ordered. Firing from the batteries began at four o'clock on the morning of the 12th of April; it lasted all that day, and was renewed on the next. Several steamers, tardily arrived with the reinforcements on board, watched the cannonade from the harbour's entrance. At one o'clock the Federal flag was hauled down, and Major Anderson surrendered on easy terms.

As being the first collision in so remarkable a war, this cannonade of Fort Sumter has a claim upon our interest, but the contemporary accounts in the American papers threw over it such an air of burlesque as it will hardly recover in the present generation. Stripped of its historical importance it has but little left; the contest may have been severe and the gallantry great, but one could not resist a smile on learning that a salute which was fired to celebrate the victory, and during which a gun burst, killing two men and wounding four others, did in a moment more serious mischief than was inflicted by the two parties together, during the incessant cannonade of one day and a half.

The news of the Federal troops having been driven by force out of the last point which remained to them between Chesapeake Bay and the Gulf of Mexico stirred up the indignation of the North. The apathy of the people was immediately changed into an intense excitement, and the passive attitude of the Government was succeeded by a due energy. War was formally declared on the next day but one to the receipt of the intelligence; 75,000 of the militia were ordered out by the same proclamation; three weeks afterwards 42,000 volunteers were called for, 22,000 men added to the regular army, and 18,000 seamen decreed for the navy.

These troops were to be furnished in set proportions by the various States, and the demand for them became a test of allegiance; in the north and north-west they were enthusiastically furnished; in other directions they were emphatically refused. The Governor of Missouri denounced immediately and strongly the requisition of troops for such an object. "Not one man," said he, "will the State of Missouri furnish to carry on such an unholy crusade." The Governor of Kentucky used similar language. Tennessee, Arkansas, Virginia, and North Carolina went further; they seceded. In Maryland the Legislature adopted a resolution which condemned the war; the Governor objected to troops from the Northern

States going through Baltimore, and the lower classes actually opposed their passage. A Massachusetts regiment on its way to Washington had to fight its way through the mob, and a Pennsylvanian regiment not yet supplied with arms was driven back from the town. To make the route positively impracticable the railway bridges were destroyed. So determined was the opposition, that levies from New England had to be sent round by sea from New York to the head of the Chesapeake, until (about the 14th of May) Baltimore was forcibly occupied by Federal troops, the railway guarded by sentinels, and martial law proclaimed.

Rapidly as the call to arms was answered on the north side of the Potomac, it could not prevent the loss of two important places which the mere presence of a few hundred men would have saved. On the 18th of April, a body of Virginians went to seize Harper's Ferry, where there was an arsenal with 15,000 stand of arms. Hearing of their approach, and unable to oppose it, the officer in charge filled the buildings with straw, set fire to the establishment, and departed. On the same day the navy yard at Norfolk was likewise abandoned and burnt. The ships lying in ordinary there were fired, or scuttled and sunk; and the only one in commission, the "Cumberland," was towed away. Nearly a year afterwards this ship was run into and sunk by the "Merrimac," one of those which the Federals had tried to destroy.

Washington itself was in considerable danger for a fortnight after the outbreak at Charleston; its escape was due to the enemy's weakness only, for it had no troops in garrison, and its situation was most exposed; on one side was Virginia, which had actually seceded, and on the other was Maryland opposing the passage of troops sent to its aid. However, by the last week in May, militia and volunteers had arrived in sufficient numbers to make it tolerably secure, and the newspapers had already planned magnificent and immediate operations, such as would crush out in a few weeks what they called the rebellion, and re-establish the Federal authority in every State. It is, then, from this time—from about the 1st of May—that the actual campaign may be said to begin; let us, therefore, in anticipation of it, cast a glance at the strength and resources of the rival Powers.

Both being without any standing army—for the few regiments employed to watch the Indian tribes were but a cipher compared to the numbers now required—we may turn at once to the population as an index of the force which might with equal convenience be raised on either side; and, having deducted from the census returns the neutral States and the slave populations, we shall see that by this rule the Federals would send into the field 340,000 for every 100,000 raised in the South. This is, of course, on the supposition that an equal desire to fight pervaded both masses of people; but if there were only half the enthusiasm for the Union as for Secession, still the men of the South, as they buckled on their swords or shouldered their muskets, must expect to be outnumbered in every engagement. Sooner or later, this human tide from the North would be pressing upon them; and where were they to look for means of strengthening their hold or of stopping its progress? Not to fortified places, for inland there were none. Not to greater facilities for moving troops from point to point, for to every forty miles of railroad in the

South there were one hundred in the North; and assuredly not to the artillery and small arms, for in these the inferiority of the South was far more conspicuous. There were but few good weapons in the arsenals and stores, and but few manufactories capable of producing them; without the command of the sea, munitions of war could not be obtained from foreign countries, and the stock might be exhausted quicker than it could be supplied.

These, then, were the circumstances under which the war began. Sixteen States of the North were arrayed against eleven of the South, and three were neutral or divided. The North had, as compared with the South, more than three times the white population, great advantages in equipment, manufactories, and railway communication; an entire command of the sea, and fourteen times the naval resources: its commerce would remain unharmed, except by an occasional privateer; and everything needful might be made at home or obtained from abroad. The South must expect to see its trade ruined, its coasts invaded, its rivers made thoroughfares at the enemy's convenience, the divided States won by force, and then—*then* the resistance she might continue to offer must depend on the unity of sentiment among all classes, and the degree of resolution which survived the trial. She might find in history glorious examples of great invasions being successfully resisted, and of weak inhabitants becoming invincible in the defence of their own firesides; but such a contest is full of bitterness and misery, and success depends on moral qualities, of whose existence we cannot be sure until we see their effects.

I will not pretend to guide you to any conclusions beyond what are based on the rude comparisons I have made; but those I beg you to keep in mind in observing the successive phases of the war.

For six weeks after war was declared the Federal troops were almost shut up in their own capital; it was not till the 23rd of May that they even occupied the suburb of Alexandria, on the opposite side of the river; and, having advanced so far, they remained stationary nearly two months, fortifying the outskirts, spending most of their time in the bar-rooms of the town, and talking always of advancing to Richmond "next week." The world in general, knowing how unfit they yet were for anything but their present employment, watched with more interest the two isolated forts called Pickens and Monroe, both of which were surrounded by Secessionists, greedy of a second bloodless victory.

Fort Monroe, which stands at the entrance to the James River, opposite Norfolk, had been strongly reinforced by the first arrivals from the North, and its commander made an effort to rid himself of his beleaguers. His attempt furnished a curious example of the blunders which may be committed by raw soldiers in the hands of equally raw officers.

Two columns, starting from different points, were to unite at the meeting of two roads, and proceed together against the enemy's position. The march was made at night, and the attack was to begin at daybreak. At the appointed time the first regiment arrived at the fork of the roads, and the second had approached to a hundred yards distance, when, without a word of notice, the first opened fire with artillery and musketry upon it. How such a fatal blunder could have been made seems inexplicable, especially as the artillery fire proves it was not confined to a few

bewildered men. There was no enemy in sight to make a confusion between friend and foe; there could have been no enemy in the direction from which this unfortunate regiment had arrived. The incident is a practical caution against using such troops for the most simply combined movements, and other instances occurred in course of the campaign to show that there was a continual risk of such a mistake.

The rest of the actions in this neighbourhood were principally engagements between coast batteries and gunboats on the Chesapeake, and creeks communicating with it,—engagements too numerous to describe, too unimportant to dwell upon; it was on the other side of Washington that the prospects or circumstances of either side were first influenced by force of arms.

Western Virginia, widely separated from the rest of the State by the parallel ranges of the Alleghany Mountains, is equally distinct in the general occupations of its inhabitants, and, as a natural consequence, in its political opinions. It held to the North; it declared itself against secession from the Federal Government, but it inconsistently passed an ordinance of secession from its own State, and proposed to create itself into a fresh one by the name of Kanawha: in the meantime it invited the presence of Federal troops for the protection and encouragement of the loyal inhabitants. In consequence of this appeal, M'Clellan moved thither from Cincinnati, on the Ohio, and entered on the campaign with energy and good fortune. His first success was at Grafton, a station where the railway to Wheeling joins that which connects Cincinnati with Harper's Ferry and Washington; his next was at Philippa, where he surprised one of the enemy's camps. Turning then towards the hill ranges, he attacked and defeated Colonel Pegram at Rich Mountain, and on the following day had a much more important success at Beverley, where he took six guns, and claimed to have routed 10,000 men, though, more probably, half that number. Coming up with the retreating army at Huttonville, he routed them again, and General Garnett, their leader, was slain. A detached force, acting under his orders in the Kanawha Valley, also had some success at Barbourville. By this series of defeats, suffered within six weeks, secession was crushed in that part of the country, and the State Government established at Wheeling was recognised at Washington as the Government of Virginia.

The cause fared but little better in that mountainous tract which lies between Western Virginia and Washington. Harper's Ferry is at the point where the easternmost ridge, as it is generally shown in maps, runs up to the River Potomac; and the neighbourhood, on either side of the river, was occupied by about 15,000 Southern troops, sent up to help those who had made the original seizure. So important a point was not likely to remain undisturbed, and at the end of May large bodies were moving thither from Pennsylvania. Their point of assembly was at Chambersburg, whence they made an advance in force on the 12th of June; from Washington 6,000 men advanced at the same time, and a column was reported to be coming simultaneously from the West. Not venturing to oppose this combination, the Southerners* abandoned the

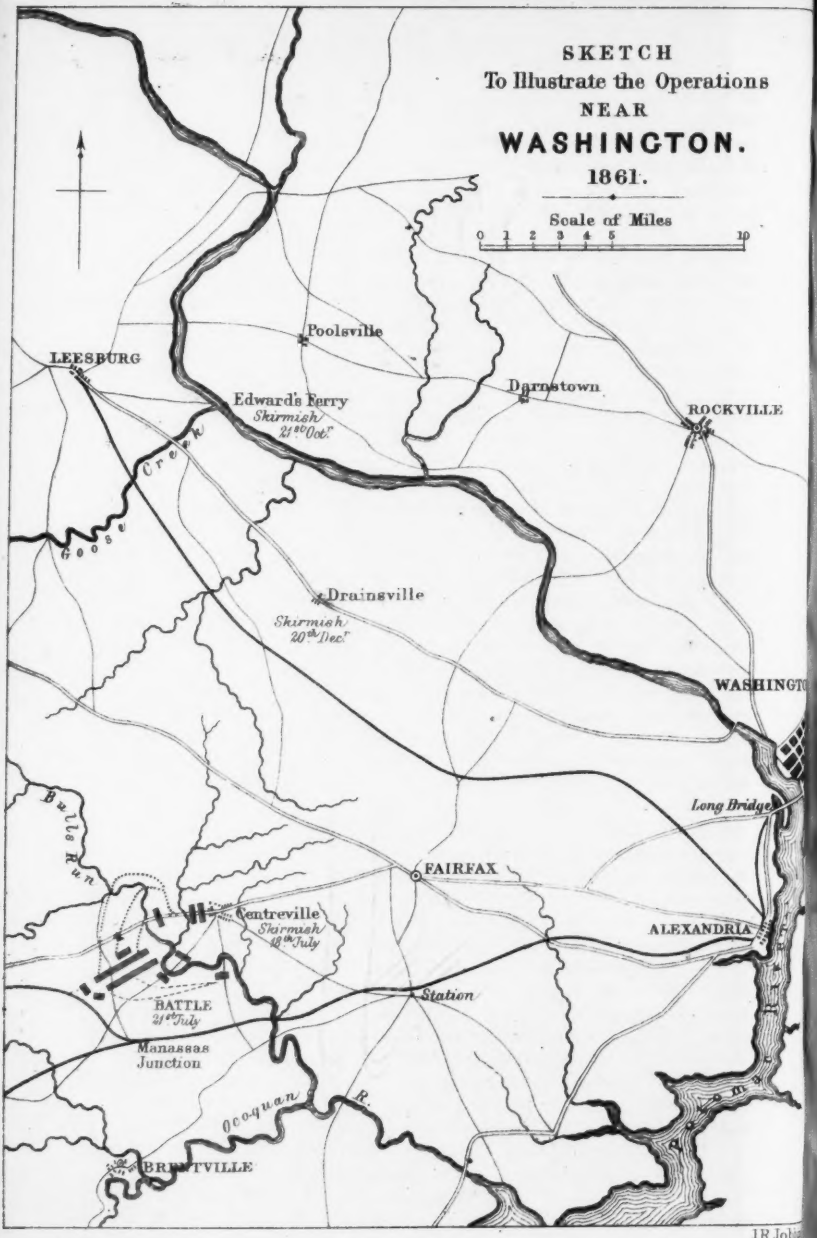
* The term "Southerners" was used throughout the lecture to avoid any misapprehension which might arise from thes imilarity of sound in Federals and Confederates.

place in good time without firing a shot. They took the direction of Winchester, followed by a brigade of Federals under Cadwallader, but before coming to a halt they turned in a north-westerly direction, and encamped at Runker's Hill, twelve miles from Martinsburg. On observing them to take this advantageous position, Cadwallader's brigade retired to the ferry. In this camp the Southerners remained for a fortnight, making one or two successful expeditions, but otherwise inactive. On the 2nd of July they received an attack, great and conclusive on paper, but without any apparent influence on their position, for on the 15th of the month the Federal forces, 15,000 strong, were again advancing upon them at the same place. General Patterson commanded these Federals; he was particularly instructed to threaten the Southerners at Winchester, and prevent them from joining their main body at Manassas, but he turned off to Charlestown, and, instead of holding the field, was said to be busy with plans for rebuilding bridges and re-opening canals. It is only fair to him to say that his division, composed of men organised on truly American principles, was as unsatisfactory a body as a general could be condemned to command. It numbered in all 20,000 men, out of which there were nineteen regiments whose short term of service was up, or would expire in a few days; and fifteen of them, he said, refused to stop one hour beyond that time. A want of transport waggons, a deficiency only too likely to exist, was another excuse offered for him, but the Government had suffered by his mistake, and would not overlook it; General Banks was sent to supersede him.

To his inactivity in not preventing any junction between the Southern troops at Winchester and those at Manassas it was convenient to attribute a great share in the disaster at Bull's Run. Just at the time when he was operating in the valley beyond the Blue Ridge, the authorities at Washington, encouraged by M'Clellan's successes, had given way to the eagerness of the people, and the Grand Army of the Potomac, so called by its admirers, had started for Richmond. You cannot need reminding what the result of that advance was. You cannot have forgotten how the American papers pronounced that the Grand Army might make another triumphal march to Canada as soon as it had reaped the laurels of this; nor how the Grand Army returned to Washington in a panic-stricken mass, officers and men hurrying along without their arms in terror and dismay, shamelessly spreading as they ran the news of their own ignominious defeat. But you may not remember so well the steps which led to that contemptible result, and those I will therefore briefly recapitulate.

The forces which marched from Washington on the 16th of July consisted of 30,000 infantry, 10 squadrons of cavalry, and 60 guns, organised in five divisions of unequal strength. General M'Dowell commanded the whole. The enemy's force was not so well known; his main body was near Manassas, where two converging lines of railway gave him easy communication with all the Southern States; his position was said to be naturally strong and skilfully fortified, but the nature of the works, and the number of the men to defend them, had been artfully kept secret.

On the 18th of July a skirmish at Centreville, magnified by the newspapers into a battle, and construed as a victory because the Southerners retired, raised the hopes and confidence of the expedition; the 19th and


SKETCH
To Illustrate the Operations
NEAR
WASHINGTON.
1861.
Scale of Miles
0 1 2 3 4 5 10
Poolsville
LEESBURG
Edwards Ferry
Skirmish
21st Oct.
Darnestown
ROCKVILLE
Goose Creek
Drainsville
Skirmish
20th Dec.
WASHINGTON
Long Bridge
Bulls Run
FAIRFAX
Centreville
Skirmish
18th July
ALEXANDRIA
Station
BATTLE
21st July
Manassas
Junction
Occoquan R.
BRENTVILLE

20th were spent in reconnoitering; and on Sunday the 21st the battle was fought.—*(See plan.)*

Between Centreville and Manassas there is a brook or river, called Bull's Run; the two roads by which it could most easily be crossed were strongly held by the enemy, but at three miles up the stream there was an unguarded ford, and another, at half the distance, almost unprotected. General M'Dowell therefore determined to move his main body round by these, to turn the enemy's left, and destroy the railway on that side. On the lower of the two roads a feint was made to distract the enemy's attention; by the other road two brigades advanced over the stream, and joined their line to that of the brigades which had crossed by the upper fords. Up to three o'clock in the afternoon all went well, but till then Beauregard, of the South, had not brought all his force into action. An important order had miscarried. He had intended to make a decisive attack early in the day by that road which M'Dowell had avoided to force, and had sent the necessary instructions to the general on that side; but, learning that nothing had been done towards executing this project, and seeing that his left was already pressed, he thought better to move to the support of the left wing the troops intended for the attack, than to risk a repulse there, which might neutralise his success elsewhere. It was not till this movement was completed that the Federals' determination was put to the proof. The issue was not yet decided, when there came on the field a brigade from that force which General Patterson was to have kept in check (part of it had previously arrived), and a second detachment leaving the train before arriving at the usual station, marched across the country, and fell upon the Federals' right and rear. "Their fire," says General M'Dowell, "caused our men to break and retire, and this soon degenerated into disorder, for which there was no remedy. Every effort was made to rally them, even beyond the reach of the enemy's fire, but in vain; the battalion of regular infantry alone moved up, and maintained itself until our men could get down to the road on the way back."

Observe, I beg, how that sentence illustrates the effect of discipline, and the difference between trained and untrained men; one battalion of real soldiers came forward at need to protect the flight of twenty times their number. But those who fled, and continued to flee, still victims to their panic, when the danger was far behind them, take at least a higher place in our opinion than those who left the ranks that day without striking a blow. The 4th Pennsylvania Volunteers and a battery of the New York Militia turned homewards as the army went into battle because their three months of service had expired. Not overlooked nor unsolicited; General M'Dowell wrote to the regiment, and the Secretary of War appealed to the battery, trying to induce them to remain, if it were but five days longer; but they insisted on their immediate discharge, and on the morning of the 21st they moved to the rear, as General M'Dowell says, "to the sound of the enemy's cannon." A disclosure humiliating but not unprecedented. I could not mention a parallel case out of America, because the conditions of military service elsewhere are so widely different; but in the American War of Independence it occurred, sadly often, that men enlisted for a few months only, refused to remain in arms beyond

that term, however imminent an action might seem, or however important their presence might be. We have seen how another part of this army suffered from the same defect, and it only remains for us to wonder that a system, which General Washington had so strongly denounced, should have been allowed to give further proofs of its utter badness.

General Beauregard stated his total force to be 27,000, and the casualties to amount to 393 killed and 1,200 wounded. M'Dowell reported 481 killed and 1,011 wounded. He estimates the number who actually crossed Bull's Run at 18,000, but that does not include four brigades posted on the roads at or near Centreville. On the whole, we may consider the forces and casualties as pretty evenly divided; but if the missing men in the Federal army could have been accurately numbered on the night of the 21st, a formidable total would have been exhibited.

The Southerners took no advantage of their victory; they merely re-occupied the heights near Alexandria, which they had once before held, and the new alarm which they inspired at Washington soon died away. They certainly cannot be said to have taught their enemies how to conquer, and yet this defeat had a more beneficial effect on the discipline and efficiency of the Federal army than if it had been an easy victory. Taught by the mortification of failure, the authorities saw the necessity of a more active commander and a more strict control; they turned to M'Clellan, as the only general whose ability had yet been stamped with success, and placed him at the head of the army.

Leaving his division in Western Virginia, he arrived at Washington on the 26th, and addressed himself forthwith to the hard task of turning Americans into soldiers. He succeeded well in that respect; the streets of Washington were less infested by idle officers and men, but the campaign was not advanced. Its history for the next six months, in this district, may be dismissed in a few words. The army was confined to the intrenchments round Washington till the 28th September, when the Southerners unexpectedly retired from the advanced position they had held. In moving out to occupy the deserted posts, certain regiments managed to repeat the blunder committed at Little Bethel, and fired upon one another with fatal effect. Eastern Virginia was occupied in November, and some great reviews took place; a few skirmishes, of which one will be noticed by and bye, may also be picked out of the American news, but no division of the army contributed so little to the first annals of the war as that which was called the Grand Army of the Potomac.

In Western Virginia the troops from which M'Clellan had been removed fell under the command of General Rosecranz, and seemed, by the newspaper accounts, to keep up their reputation for activity and good fortune. Scarcely a mail arrived without the news of some gallant skirmish or important victory, but the result of them all was that the little campaign which began at Gawley Bridge on the Kanawha terminated at the very same point; and the neighbourhood of Beverley, where M'Clellan had won his last battle, was the scene of another victory ten weeks afterwards. In short, when the troops went into winter quarters they were no further advanced in the State than they had been four months earlier in the year.

In the north of Virginia there were also many little combats of a kindred nature to those in the West, similarly described and equally extolled, but foiled by one reverse which could neither be passed over in silence nor transformed into a victory. Being of more importance and interest than the rest, it claims a few moments of your attention. At Leesburg, 30 miles north-west from Washington, a part of the Southern army was stationed, the Potomac River, a few miles off, separating the outposts from those of the Federal division under General Banks, whose headquarters were at Darnstown—(*see plan*). Under him was General Stone at Poolesville, and Colonel Baker commanded the regiments nearest to the river. To this officer General Stone sent a sudden and laconic order to make a dash at Leesburg. Over the river, swollen with heavy rains, 400 men were sent by night in a few small boats; in the early morn they pushed on boldly, but rashly without support, to Leesburg, found the enemy there, and were quickly obliged to return to the river side. Small reinforcements were sent over to their help, and in the afternoon Colonel Baker came to take the command. The Southerners were superior in number, but had no artillery; the Federals had three guns, but the ground was unfavourable for their use. About four o'clock Colonel Baker was shot, and the Federals, gradually despairing of driving back the enemy, began to seek means for their own retreat. And then came the terrible scene which cannot fail to come when the rushing current of a wide river has to be crossed by beaten men with insufficient means at their disposal: such scenes have been often described, and only repeat themselves; let figures tell the story of this. Of 1,800 men who had left the Maryland side, one-third were left on the opposite bank, the three pieces of artillery were lost, and in one regiment there were said to be only two swords, and not one musket, left.

So great was the alarm created by this disaster that the Federals might have suffered seriously if they had been attacked immediately in that part of the line; but except that the Southern troops at Leesburg were reinforced, as if such a thing were intended, the action at Edward's Ferry (or Ball's Bluff) made no difference in their relative situations, and within a couple of months a chance skirmish took place between Leesburg and Washington, in which the fortune of war inclined to the opposite side. The scene of the encounter was at Drainesville, and the contest was occasioned by sending an expedition to take a quantity of forage which the Secessionists had collected there. The action was sharper than usual; on each side a brigade with some artiliery was engaged, but that of the Federals was stronger than the other, and the affair lasted but one hour. Forty of the enemy were found dead on the ground, and fifty loads of forage, with two ammunition waggons, were brought back in triumph to Washington.

In the same column of the "Times" with the official report of the Drainesville engagement there was also the announcement that elsewhere a camp had been surprised, and the Southerners in it, with their arms, waggons, and tents, captured by hundreds. At first sight it seemed to form part of the operations in or near Virginia; it was really as independent of them in plan as it was remote in situation, and to the country where it happened I must now invite your attention, a country as far from

that term, however imminent an action might seem, or however important their presence might be. We have seen how another part of this army suffered from the same defect, and it only remains for us to wonder that a system, which General Washington had so strongly denounced, should have been allowed to give further proofs of its utter badness.

General Beauregard stated his total force to be 27,000, and the casualties to amount to 393 killed and 1,200 wounded. M'Dowell reported 481 killed and 1,011 wounded. He estimates the number who actually crossed Bull's Run at 18,000, but that does not include four brigades posted on the roads at or near Centreville. On the whole, we may consider the forces and casualties as pretty evenly divided; but if the missing men in the Federal army could have been accurately numbered on the night of the 21st, a formidable total would have been exhibited.

The Southerners took no advantage of their victory; they merely re-occupied the heights near Alexandria, which they had once before held, and the new alarm which they inspired at Washington soon died away. They certainly cannot be said to have taught their enemies how to conquer, and yet this defeat had a more beneficial effect on the discipline and efficiency of the Federal army than if it had been an easy victory. Taught by the mortification of failure, the authorities saw the necessity of a more active commander and a more strict control; they turned to M'Clellan, as the only general whose ability had yet been stamped with success, and placed him at the head of the army.

Leaving his division in Western Virginia, he arrived at Washington on the 26th, and addressed himself forthwith to the hard task of turning Americans into soldiers. He succeeded well in that respect; the streets of Washington were less infested by idle officers and men, but the campaign was not advanced. Its history for the next six months, in this district, may be dismissed in a few words. The army was confined to the intrenchments round Washington till the 28th September, when the Southerners unexpectedly retired from the advanced position they had held. In moving out to occupy the deserted posts, certain regiments managed to repeat the blunder committed at Little Bethel, and fired upon one another with fatal effect. Eastern Virginia was occupied in November, and some great reviews took place; a few skirmishes, of which one will be noticed by and bye, may also be picked out of the American news, but no division of the army contributed so little to the first annals of the war as that which was called the Grand Army of the Potomac.

In Western Virginia the troops from which M'Clellan had been removed fell under the command of General Rosecranz, and seemed, by the newspaper accounts, to keep up their reputation for activity and good fortune. Scarcely a mail arrived without the news of some gallant skirmish or important victory, but the result of them all was that the little campaign which began at Gawley Bridge on the Kanawha terminated at the very same point; and the neighbourhood of Beverley, where M'Clellan had won his last battle, was the scene of another victory ten weeks afterwards. In short, when the troops went into winter quarters they were no further advanced in the State than they had been four months earlier in the year.

In the north of Virginia there were also many little combats of a kindred nature to those in the West, similarly described and equally extolled, but foiled by one reverse which could neither be passed over in silence nor transformed into a victory. Being of more importance and interest than the rest, it claims a few moments of your attention. At Leesburg, 30 miles north-west from Washington, a part of the Southern army was stationed, the Potomac River, a few miles off, separating the outposts from those of the Federal division under General Banks, whose headquarters were at Darnstown—(*see plan*). Under him was General Stone at Poolesville, and Colonel Baker commanded the regiments nearest to the river. To this officer General Stone sent a sudden and laconic order to make a dash at Leesburg. Over the river, swollen with heavy rains, 400 men were sent by night in a few small boats; in the early morn they pushed on boldly, but rashly without support, to Leesburg, found the enemy there, and were quickly obliged to return to the river side. Small reinforcements were sent over to their help, and in the afternoon Colonel Baker came to take the command. The Southerners were superior in number, but had no artillery; the Federals had three guns, but the ground was unfavourable for their use. About four o'clock Colonel Baker was shot, and the Federals, gradually despairing of driving back the enemy, began to seek means for their own retreat. And then came the terrible scene which cannot fail to come when the rushing current of a wide river has to be crossed by beaten men with insufficient means at their disposal: such scenes have been often described, and only repeat themselves; let figures tell the story of this. Of 1,800 men who had left the Maryland side, one-third were left on the opposite bank, the three pieces of artillery were lost, and in one regiment there were said to be only two swords, and not one musket, left.

So great was the alarm created by this disaster that the Federals might have suffered seriously if they had been attacked immediately in that part of the line; but except that the Southern troops at Leesburg were reinforced, as if such a thing were intended, the action at Edward's Ferry (or Ball's Bluff) made no difference in their relative situations, and within a couple of months a chance skirmish took place between Leesburg and Washington, in which the fortune of war inclined to the opposite side. The scene of the encounter was at Drainesville, and the contest was occasioned by sending an expedition to take a quantity of forage which the Secessionists had collected there. The action was sharper than usual; on each side a brigade with some artiliery was engaged, but that of the Federals was stronger than the other, and the affair lasted but one hour. Forty of the enemy were found dead on the ground, and fifty loads of forage, with two ammunition waggons, were brought back in triumph to Washington.

In the same column of the "Times" with the official report of the Drainesville engagement there was also the announcement that elsewhere a camp had been surprised, and the Southerners in it, with their arms, waggons, and tents, captured by hundreds. At first sight it seemed to form part of the operations in or near Virginia; it was really as independent of them in plan as it was remote in situation, and to the country where it happened I must now invite your attention, a country as far from

Washington or the banks of the Potomac as the coasts of Africa or the boundaries of Russia are from our own metropolis.

Where the waters of the Ohio unite with the Mississippi, after inclining towards one another for 150 miles, public feeling is divided between attachment to the Union and determination to secede. Kentucky and Tennessee on the east, and Missouri on the west, long halted between the two opinions, and the southern counties of Illinois, above the meeting of the rivers, were affected by a Secessionist tendency, though they had not weight enough to control or influence the policy of the State. Cairo, therefore, as its most southern point, was early occupied by Federal troops, whilst Randolph, below the doubtful States, was the headquarters of the Secessionist force. Thus stood the two parties when Fort Sumter fell, and President Lincoln called for troops to crush the rebellious South. In Missouri the Governor characterised the requisition—I quote his words—as "illegal, unconstitutional, revolutionary, inhuman, and diabolical;" but there were many people ready to apply equally strong epithets to his own despatch, and a contest in the State immediately began. Forces were raised for the cause of the Union; their appointed General, Lyon, refused to disband them at the Governor's order, and, when the State militia was called out to enforce the command, he began the campaign by attacking and defeating a part of it at Booneville.

His personal career was but a short one. The Governor's troops, commanded by General Price, having moved towards the south-west, he followed in pursuit. His van-guard engaged them at Carthage on the 5th of July, and his main body came up with them on the 10th of August, near Springfield. An action ensued, of which the result was important, and the description curious. It begins by telling how 8,000 Federals attacked 23,000 Southerners, spread slaughter and dismay in their ranks, killed two of their generals, and destroyed all their tents and waggons: it ends by a brief remark that the very army which had done so much had retreated several miles, and might be considered *safe*. And by degrees these facts became evident, that it was the Federals who were defeated; that they lost a gun; that General Lyon was killed on the field, and that St. Louis itself was in danger of capture.

Instead, however, of attacking the head-quarters of the Federalists, General Price took a northerly direction, and shortly appeared before Lexington, on the Missouri, where he was joined by a body of troops from the neighbouring state of Kansas, and fresh levies raised by Governor Jackson. An entrenched camp near the river was occupied by 3,500 Federals; on this, when his force was fully assembled, General Price opened fire; 1,500 men coming to its relief from Richmond, in the north-west, were easily driven back; and on the evening of the 20th September the place was surrendered.

Its loss was angrily felt by the Federalists; the whole garrison, with artillery, stores of considerable value, 900,000 dollars in money, and an important position, had been allowed to fall into the enemy's hands; strong indignation was expressed against General Fremont, who commanded at St. Louis, for omitting to send such reinforcements as would have prevented it, and preparations were made to recover the post. Fremont himself started on this expedition, but by the time he reached Jefferson City, Price

had retired towards the town of Independence, whence he soon returned to the south-west of the State. The Federals followed him in several divisions by various routes, and on the 25th October there was a skirmish between them at Springfield, but Price was expecting to be joined by a division under General M'Culloch, and till then it was not his interest to fight a battle. Even after the junction he continued to retire until he reached the boundaries of Arkansas. About that time a change took place in the command and movements of the Federal army. General Fremont was superseded by Hunter, and the divisions in this part of the State began to retrace their steps. Price in his turn became the pursuer, and was back at Springfield by the 25th November.

During the winter months of December and January both parties remained inactive—the Federals did not claim a single victory.—February had arrived when they began to assemble their divisions preparatory to attacking Price, who was still in his old quarters at Springfield. When they advanced upon him he repeated his old tactics of retiring towards Arkansas—there the fighting began. Whether he was brought to bay, or whether he voluntarily took the offensive, I cannot say; but there was a series of engagements extending over several days, and comprising an important battle at a place near Bentonville, called Pea Ridge. In this, M'Culloch, one of Price's generals, was reported to be killed and the Southern force entirely dispersed, but I have seen no official despatch or authentic account of the battle; and by the last intelligence the Federals had fallen back into Missouri, which is no sign of success, whatever policy may have dictated the step. Many of these victories assume very small proportions when measured by the results which attend them.

You will do well to remember that all our intelligence is derived from Northern sources, and the accounts of one side only are never a safe authority. In any war we can only approach the truth by carefully weighing the statements of both parties, which, in this one, are beyond our reach. The case of the Southerners is that of the lions in the fable, who were always shown in pictures as being killed by man, because lions were never the painters.

The engagement to which I referred on beginning this account of the war in Missouri, was one of those disconnected affairs with which every civil war abounds. Here they pervaded the whole State; in the north part they occurred near the Mississippi, or along the railway which connects the western interior with the great lakes of the North. In the south-east the scene of them was near Fredericton, the point in dispute there being apparently the command of that unfinished railway which is to give the town of St. Louis a direct communication with Memphis, and thence with the Gulf of Mexico and the Atlantic Ocean. Also from the frontiers of Kansas there were occasional tidings of conflicts, and along the banks of the Lower Mississippi parties of Federals from Cairo occasionally landed, fought, and returned whence they had set out. The Federals were undoubtedly stronger in arms, but their force was not applied with corresponding success. It was in Missouri as it had been in Virginia: the want of an established military system retarded the development of their resources, and impeded the application of their strength; it made the excellent weapons with which they were armed comparatively

useless in their hands; it put the wretchedly-equipped levies of the South on almost equal terms with their adversaries; and, had not the vast numbers of the Federal army been assisted by an irresistible naval force, another season might have passed away without bringing any return for the profuse military outlay of the war. On the sea coast, where the broadsides of the ships could overpower the batteries on land, bodies of Federal troops had lodged themselves; in districts where any sympathy was shown by the people the superiority of the Federal strength had also made itself felt; and now an expedition was being prepared in which both these allies would be brought into play. Starting from Cairo for the invasion of Kentucky and Tennessee, and following the course of two navigable rivers, it would be accompanied by iron-plated gunboats, would be assisted by all the water transport of the country, and would penetrate two States whose inhabitants were partly favourable to its success.

For a long time these two States had enjoyed an immunity from the scourge of the war. Kentucky professed a strict neutrality; refusing to furnish troops to the North, it equally declined to secede with the South; professing a desire for nothing but peace, it protested against either of the combatants occupying its soil or even crossing its territory. Tennessee, more committed to secession, was secure from hostilities so long as the protests of Kentucky were respected; but at the beginning of September the Southerners presumed to occupy Hickman, and the Federals Paducah: both disregarded the Governor's injunctions to quit, and at once Kentucky became a new theatre of war.

The Federals were along the Ohio River, the northern boundary of the State, posted principally at Cincinnati and Cairo, with a footing in the State at Louisville and Paducah. For them a perfect network of railways communicated with all parts of the rear. For the Southerners there were only two lines, leading from the Ohio River to the interior of the country; one through Nashville, the other through Humboldt; but the natural features which had prevented the construction of railways might serve well in a defensive campaign, and the Cumberland Mountain range, which traverses the district, might prove a useful ally in time of need.

Columbus on the Mississippi was for a time the principal Southern camp; but according as the Federals threatened to advance from Henderson, Louisville, and Cincinnati, Bowling Green in the centre was occupied by troops under General Buckner, and the western part by others, under General Zollicoffer. The latter was the first to be engaged. The Federals arrived in his neighbourhood early in October, and on the 21st he made an unsuccessful attack upon them. Again, on the 13th of December, he was reported to be moving from Cumberland River to Somerset, and a fight was said to be imminent. On the 19th of January he fulfilled this expectation by again taking the initiative. How he had employed the interval of a month between places which are only twenty miles apart, I cannot explain; but the immediate inducement for the attack was that the enemy's force had divided—one part remaining in camp, whilst the other made a flanking movement. To seize this opportunity sounds both bold and wise, but the result was highly unfortunate; General Zollicoffer himself was killed, his men were driven back to their camp, and, being pursued and attacked there, fled again, leaving behind them

10 field guns, 100 waggons, 1,200 horses, and a great quantity of small arms and stores. General Crittenden, next in command, rallied them at Monticello, but soon made a further retreat, and the Federals followed them up.

This defeat amounted to a disaster, so serious an aspect did it bear from every point of view. The loss of so much matériel was a serious blow to an army so imperfectly equipped. The loss of the position and disorganization of the troops exposed the flank of their main line to be turned by an enemy numerous enough to do so without risk, and the repulse itself had a disheartening effect on their courage, coming as it did in the wake of the long fruitless struggle in Missouri, and their recent defeat at Drainesville, in Virginia. I was near adding to the list another battle lately fought in the corner of Kentucky, near Pikeville, a hundred miles from Somerset, by which a Brigadier General Nelson suddenly became famous. The Confederates captured and slain by his skill were, it appeared, exactly 2,415, including two generals; and I should have liked to describe the wonderful manœuvre—for it was a wonderful one—by which he was reported to have secured the result.

But on coming to the newspapers of a fortnight's later date, I had to strike out the notes I had made. "Somebody," as Mr. Russell said, "had blown the general's trumpet a little too loud and a little too long." There were 25 killed—not 400; there were 50 prisoners instead of 2,000; and the battle was without a manœuvre at all; "but it was a glorious victory," an American paper still said, "and has rejoiced the hearts of the nation and greatly cast down its enemies." Glorious or not (and I should say *not*), any success was valuable in that part of the State whilst General Thomas was moving from Somerset towards the Cumberland Mountains, and troops from Cincinnati and other points on the Ohio were marching southwards for Bowling Green.

At this place, the junction of two railways, the Southerners were in considerable numbers, under General Buckner. Further west they were stronger still; 40,000 men were said to be at Columbus, and an attack upon Paducah was hinted at, but there was no fighting beyond a few skirmishes, until General Grant's expedition entered the State.

With nineteen regiments of infantry, four of cavalry, and seven batteries of artillery, an important addition to the troops already in Kentucky, General Grant arrived at Paducah on the 15th January. A flotilla of gunboats, prepared to steam up any navigable river, was ready to take part in the expedition, and their heavy guns, protected by plated sides, were more numerous and far more formidable than the field artillery of the force. Fort Henry, against which the first operations were to be directed, was an earthwork on the river Tennessee, a little outside the boundary line of Kentucky; thrown up by the Federals during the previous summer, it had not strength of construction to resist a long attack from superior forces, and, commanded by higher ground on both sides of the river, it could only be regarded as an useful outpost, to be given up, when attacked, if it could not be adequately supported. Reinforcements to the amount of three or four regiments were sent thither when it was first threatened, but these were barely enough to guard a retreat; they encamped outside and retired without fighting; only sixty men remained inside to fight the guns,

which should have had twice or thrice that number for their service. When, therefore, the seven gunboats opened their fire, they reduced the place in one hour and ten minutes without any aid from General Grant, though in doing so they suffered more than twice the loss they inflicted on the garrison, and one was utterly disabled. A general, named Tilgham, and the sixty men, were taken prisoners; ten heavy guns, ten light ones, and seventeen mortars were found in the place, and for what purpose the mortars could have been placed there I am at a loss to conceive. The fort itself was flooded by the rising of the stream, and had to be abandoned within a week, a sufficient proof of the badness of the site.

In the meantime General Grant had moved across from the Tennessee to the Cumberland River, which here runs in a parallel direction at ten miles distance. At Dover, on the Cumberland, the Southerners had entrenchments of considerable extent, held by a considerable body of men; and they knew that much depended on the firmness of their stand here. Long before the fall of Fort Henry, before even the expedition had left Cairo, a Richmond paper had noticed the threatening aspect of Buell's formidable force near Bowling Green, and had clearly pointed out the disasters that might ensue if this point were forced. Since then Thomas had defeated Zollicoffer in the east of the State, Mitchell's division had advanced to Bowling Green in the centre, and thirty-five regiments, aided by gunboats, were ready to attack their stronghold in the West. The crisis had become more serious; to meet it they had sent for the general reputed to be their most able commander, Albert Johnson, and had brought Beauregard, the victor at Bull's Run, with 15,000 men, from Virginia to Kentucky: neither of these, however, were at Dover when the fatal day arrived.

The interval between the 6th February, when Fort Henry was taken, and the 15th February, when the entrenched position at Dover, called Fort Donnelson, was attacked, was spent in marching over the country and investing the place. At daylight on the 15th the action was begun by the opposite side; the Southern generals, finding that they were surrounded by the enemy, cut off from supplies, and imperfectly defended by their earthworks, resolved to take the offensive, hoping to obtain at least such a success as would enable them to open a gap for retreat through the investing lines. For a time they were successful; they drove back the right wing on the centre, and had managed to capture an entire field battery; but, whilst so engaged, part of their own entrenchments had been stormed and won, and their efforts to dispossess the new occupants were of no avail. The loss of this point, which commanded the rest of the line, made it doubtful whether they could hold out one more day; but retreat was again as difficult as it had been before the sortie, for the enemy had reoccupied his former positions, and all the day's labour had been thrown away.

A second council of war was therefore held, and a very remarkable course was adopted. Of three generals, Floyd, the senior, thought it useless to fight, but vowed he would not surrender; Pillow, the next, was in favour of fighting; Buckner, the third, preferred a surrender to every other course. That generals in council should hold opposite opinions is not extraordinary; but never, I should think, has any difference been

terminated or reconciled like this. General Floyd gave up the command to Pillow, on condition of being allowed to retire with his own brigade; Pillow in his turn made it over to Buckner on a similar condition, that his own personal movements should be left unfettered; and Buckner, then able to act on his own opinion, surrendered the whole force on no condition at all. This triple transfer finished the episode of Fort Donnelson.

The Federals claim to have taken 13,300 prisoners, and a list, purporting to be official, gives by name the regiments, twenty in number, to which they belonged. General Pillow, however, reckoned the whole force at only 12,000, of whom many were killed during the action, and one brigade escaped. The discrepancy is large. The escape of General Floyd's brigade also requires explanation, for a single gunboat of the flotilla might have prevented it, and three or four thousand men could hardly have been embarked without being detected by a reasonably watchful enemy.

On the day that the fate of Fort Donnelson was settled, Bowling Green likewise was occupied by the Federals. That the division there should soon unite with Grant's, that Nashville, which lies defenceless on the Cumberland River, should be taken without resistance, and that the Southerners should choose some point in the less accessible country on the south or south-east for their next contest, was only to be expected. The question was, how far the Federals could dispense with the aid which the navigable rivers had hitherto offered them, both in convenience of transport and in power of artillery. At the time that I was writing this, a month after the news of Fort Donnelson's capture had arrived, the intelligence from that part of the country had dwindled to nothing, the advance was in abeyance; let us take the opportunity of tracing the various expeditions which have been made to vulnerable points on the Atlantic coast.

They may be distinguished as Butler's, Sherman's, and Burnside's. Butler's, the first, mustering 4,000 men, and backed by men-of-war bearing 100 guns, left Fort Monroe on the 26th of August, and appeared before Hatteras, or Ocracoke Inlet, the evening of the 27th. This channel, the entrance to an interior sea, was guarded by two small forts. To make a combined attack upon them by land and sea, the disembarcation of the troops began, but a heavy sea stopped it, and the men-of-war opened their fire without waiting for it to be completed. Considering that the larger of these forts embraced only two-thirds of an acre, and that both were mere field-works, mounting only 17 guns between them, we need not be surprised that they soon succumbed. The smaller was evacuated the first day of the attack, the second capitulated early next morning, and 700 prisoners, with 1,000 stand of arms, were included in the surrender. The casualties in them amounted to about fifty killed and wounded; on the other side there were none, owing to the troops not having been engaged, and the ships having judiciously kept as far off as possible. The fleet soon departed. The troops and a few gunboats remained to hold the place, but nothing occurred of sufficient importance to be mentioned here; the conquest was barren of results; it did not stop the Southerners, as was intended, from navigating those inland seas; it did

which should have had twice or thrice that number for their service. When, therefore, the seven gunboats opened their fire, they reduced the place in one hour and ten minutes without any aid from General Grant, though in doing so they suffered more than twice the loss they inflicted on the garrison, and one was utterly disabled. A general, named Tilgham, and the sixty men, were taken prisoners; ten heavy guns, ten light ones, and seventeen mortars were found in the place, and for what purpose the mortars could have been placed there I am at a loss to conceive. The fort itself was flooded by the rising of the stream, and had to be abandoned within a week, a sufficient proof of the badness of the site.

In the meantime General Grant had moved across from the Tennessee to the Cumberland River, which here runs in a parallel direction at ten miles distance. At Dover, on the Cumberland, the Southerners had entrenchments of considerable extent, held by a considerable body of men; and they knew that much depended on the firmness of their stand here. Long before the fall of Fort Henry, before even the expedition had left Cairo, a Richmond paper had noticed the threatening aspect of Buell's formidable force near Bowling Green, and had clearly pointed out the disasters that might ensue if this point were forced. Since then Thomas had defeated Zollicoffer in the east of the State, Mitchell's division had advanced to Bowling Green in the centre, and thirty-five regiments, aided by gunboats, were ready to attack their stronghold in the West. The crisis had become more serious; to meet it they had sent for the general reputed to be their most able commander, Albert Johnson, and had brought Beauregard, the victor at Bull's Run, with 15,000 men, from Virginia to Kentucky: neither of these, however, were at Dover when the fatal day arrived.

The interval between the 6th February, when Fort Henry was taken, and the 15th February, when the entrenched position at Dover, called Fort Donnelson, was attacked, was spent in marching over the country and investing the place. At daylight on the 15th the action was begun by the opposite side; the Southern generals, finding that they were surrounded by the enemy, cut off from supplies, and imperfectly defended by their earthworks, resolved to take the offensive, hoping to obtain at least such a success as would enable them to open a gap for retreat through the investing lines. For a time they were successful; they drove back the right wing on the centre, and had managed to capture an entire field battery; but, whilst so engaged, part of their own entrenchments had been stormed and won, and their efforts to dispossess the new occupants were of no avail. The loss of this point, which commanded the rest of the line, made it doubtful whether they could hold out one more day; but retreat was again as difficult as it had been before the sortie, for the enemy had reoccupied his former positions, and all the day's labour had been thrown away.

A second council of war was therefore held, and a very remarkable course was adopted. Of three generals, Floyd, the senior, thought it useless to fight, but vowed he would not surrender; Pillow, the next, was in favour of fighting; Buckner, the third, preferred a surrender to every other course. That generals in council should hold opposite opinions is not extraordinary; but never, I should think, has any difference been

terminated or reconciled like this. General Floyd gave up the command to Pillow, on condition of being allowed to retire with his own brigade; Pillow in his turn made it over to Buckner on a similar condition, that his own personal movements should be left unfettered; and Buckner, then able to act on his own opinion, surrendered the whole force on no condition at all. This triple transfer finished the episode of Fort Donnelson.

The Federals claim to have taken 13,300 prisoners, and a list, purporting to be official, gives by name the regiments, twenty in number, to which they belonged. General Pillow, however, reckoned the whole force at only 12,000, of whom many were killed during the action, and one brigade escaped. The discrepancy is large. The escape of General Floyd's brigade also requires explanation, for a single gunboat of the flotilla might have prevented it, and three or four thousand men could hardly have been embarked without being detected by a reasonably watchful enemy.

On the day that the fate of Fort Donnelson was settled, Bowling Green likewise was occupied by the Federals. That the division there should soon unite with Grant's, that Nashville, which lies defenceless on the Cumberland River, should be taken without resistance, and that the Southerners should choose some point in the less accessible country on the south or south-east for their next contest, was only to be expected. The question was, how far the Federals could dispense with the aid which the navigable rivers had hitherto offered them, both in convenience of transport and in power of artillery. At the time that I was writing this, a month after the news of Fort Donnelson's capture had arrived, the intelligence from that part of the country had dwindled to nothing, the advance was in abeyance; let us take the opportunity of tracing the various expeditions which have been made to vulnerable points on the Atlantic coast.

They may be distinguished as Butler's, Sherman's, and Burnside's. Butler's, the first, mustering 4,000 men, and backed by men-of-war bearing 100 guns, left Fort Monroe on the 26th of August, and appeared before Hatteras, or Ocracoke Inlet, the evening of the 27th. This channel, the entrance to an interior sea, was guarded by two small forts. To make a combined attack upon them by land and sea, the disembarcation of the troops began, but a heavy sea stopped it, and the men-of-war opened their fire without waiting for it to be completed. Considering that the larger of these forts embraced only two-thirds of an acre, and that both were mere field-works, mounting only 17 guns between them, we need not be surprised that they soon succumbed. The smaller was evacuated the first day of the attack, the second capitulated early next morning, and 700 prisoners, with 1,000 stand of arms, were included in the surrender. The casualties in them amounted to about fifty killed and wounded; on the other side there were none, owing to the troops not having been engaged, and the ships having judiciously kept as far off as possible. The fleet soon departed. The troops and a few gunboats remained to hold the place, but nothing occurred of sufficient importance to be mentioned here; the conquest was barren of results; it did not stop the Southerners, as was intended, from navigating those inland seas; it did

not serve as a base for further operations, and its occupation was attended with great sickness in the winter months.

The next expedition, Sherman's, was on a larger scale. It was composed of fourteen regiments and one field battery; its escort was twenty-seven men of war, with 400 guns, and its equipment included everything necessary for fortifying the point at which they might land. That point was a secret; in reality it was not fixed, but was left for circumstances to decide. Port Royal was eventually chosen, and the ships weighed anchor on the 29th October.

A severe storm on the way protracted the passage, scattered the fleet, and wrecked some of the transports. Arrived at Port Royal, the means of disembarking the regiments were found to be so much reduced, that the attack on the forts at the harbour's mouth was left to the ships alone. The bar which threatened to prevent the entrance of the larger men-of-war having been safely passed the engagement was opened. In four hours both of the principal batteries were silenced, and the Southerners' gunboats lying behind them, unable to render any efficient help, had dispersed to seek their own safety.

The white inhabitants of the neighbouring town of Beaufort fled; the negroes remained, but there was as little aid to be got from the latter as there was Union feeling to be found in the former. The first use to which Port Royal was applied was to send from it those stone-laden ships which were to be sunk at the entry of Charleston Harbour, to close it, not only for the present, but the future,—to fill it and choke it for evermore. You remember, I dare say, what indignation was expressed in Europe at such a deed, and you may remember that, to turn away the reproach, the New York papers pleaded that they only wished to bar the entrance which they could not closely blockade, and that another, in some respects better, channel remained open as a proof of their forbearance.

It is true that another channel did remain open, that they had forborne to close it; but the Admiralty chart suggests for that forbearance the charity which begins at home. The bar which stretches in front of Charleston is crossed by the main channel at six or seven miles from the forts at the harbour's mouth; but it is crossed by the other channel at a few hundred yards only from the northern fort, and the deep water outside widens like a fan, so that obstacles to prevent the passage of ships must be sunk at that one point, or not at all. Whilst, therefore, in one case they could work their will in safety, in the other they must approach under the point-blank range of heavy guns. Judge for yourselves how far this may have effected the safety of the second channel.

To return to Port Royal. At the end of November Tybee Island was occupied, by which the entrance to Savannah was commanded, and Fort Pulaski might be attacked: it has been attacked, is still under attack, but has not yet (10th April) fallen. In March, the activity which pervaded the whole war extended itself to this expedition, and two other places on the coast, Brunswick and Fernandina, each the terminus of a railway, were likewise seized; here we must leave it, that we may bring the narrative of General Burnside's expedition down to the same date.

This expedition, starting, like Sherman's, for an unknown destination, sailed from the Chesapeake on the 11th January, just at the time when

Grant's force was assembling for the invasion of Tennessee. On the 15th it entered Hatteras Inlet, and on the 7th February it made an attack on the island of Roanoke, a spot already known to American history as the place where the first discoverers sent out by Raleigh were hospitably entertained by the Indians, and where the earliest settlement was made in the State whose capital now bears his name. The island, which commands the channel between Albemarle and Pamlico Sounds, is about twelve miles long, and was defended by 3,000 men, six batteries mounting forty-two guns, and eight steamers carrying two guns each. The Federals attacked it by land and sea. They were, as usual, superior in numbers, and the Southerners, as usual, had no defences of sufficient worth to restore the balance of strength. Their main body rested on an earthwork into which a man might walk, and which was attacked on three sides at once; their retreat was limited by the extent of the island, and the result need hardly be told. Everything was lost: the gun-boats indeed retired to Elizabeth Town up a creek on the north side of the Sound, but were followed and destroyed there.

Newbern, which is also within reach of the navy, fell, on the 14th March, after very similar operations; Beaufort and Washington have been taken uncontested. Many, therefore, are the points at which the Federals have now effected lodgements in the rival republic; I will briefly describe their present position (24th April). In Western Virginia they occupy the Kanawha Valley, and most of the country west of the Alleghany Mountains. In Northern Virginia they have begun to advance down the valley of the Shenandoah (an advance which occasioned the late action of Winchester), and have occupied the country for some distance from Washington towards Richmond, so far as it is not defended by the enemy.

On the eastern side, near Fort Monroe, the army under General M'Clellan (no longer commanding in chief the whole of the forces) has safely landed from the boats which brought it down the Chesapeake, and is about to attack a formidable Southern division at Yorktown. At Beaufort (North Carolina), Fort Macon, held by a few hundred men, will probably soon fall into the Federals' hands, and Fort Pulaski, at Savannah, surrounded and famishing, is said to have already offered a surrender.* Brunswick in Georgia, Fernandina and Jacksonville in Florida, have been occupied by the Federals. Fort Pickens has never been taken from them, and a formidable expedition of land and sea forces is engaged in the reduction of New Orleans. How it fares with them we are not allowed to know; a fortnight has passed since we heard of their being in the immediate neighbourhood, and so entirely is the press in the power of the Government that silence cannot mean success, whilst it may imply anything between victory and disaster.

Far up the Mississippi, beyond the borders of Tennessee, the Federals have skilfully captured the island above New Madrid, called No. 10; and in the south of the same State, close to the point where the River Tennessee enters Alabama, the greatest battle ever fought in America has just taken place. It was only on Wednesday last that the details were pub-

* News of its capture arrived a few days afterwards.

lished, and I need not enter into them. The Federal troops engaged were a part of General Grant's force, moved thither from Dover and Nashville, supported by those who had come through the middle of Kentucky from the Ohio. The Southerners had been collected from Pensacola and various other points; their arrangements seem to have deserved success, and I regret to see that among their killed was the general reported to be their most able commander, Albert Sydney Johnston. His loss will be a blow to their confidence, which they can ill afford to suffer; and by his death America loses a good soldier who might have raised her military reputation.

From Eastern Tennessee we have had no news of importance since Nashville was taken; Kentucky I believe to be exclusively occupied by the Federals, and Missouri to be generally in their hands.

If I have taken no notice of the combat between the "Monitor" and "Merrimac" it is because the result has not influenced the military progress of the war; its interest depends on considerations which would only distract your attention from the general history; and to treat it as it ought to be treated would detain me too long. Already the narrative has extended so far, that I have but little time to touch upon the wide and inviting field of review, and the following brief remarks are all that I can venture to offer.

With immense manufacturing resources, extensive commerce, and freedom from public debt, the Federals had at the outset everything that a nation could want for the purposes of war, *except* an army. For want of it their capital had once been burnt, but during the fifty years which followed they encountered no foe more formidable than Texas and Mexico, and, far from desiring to change their military system, they held it to be the best that they could maintain. Their militia was reckoned at three millions; their regular army numbered seventeen weak regiments, whose companies, employed in guarding the interior States against Indian forays, did not form one single brigade of the troops sent into the field. It was, therefore, with untrained men, inexperienced officers, and generals snatched from civil pursuits, that the Federals talked of conquering forthwith the seceded States. If they had fulfilled one hundredth part of their task in the time they named the world would have been amazed. The professional soldier's life would, indeed, be wasted, and his occupation might well be gone, if thousands of men thus hurriedly called under arms could be marched and manœuvred at will. That they could be thus handled no disinterested person was sanguine enough to suppose, but nothing less than an unmitigated failure like Bull's Run would have convinced the American journalists that their militiamen were not (to use their own words) "better than French soldiers."

Of the interior state of the Southern army we have heard little; but the glimpses which Mr. Russell obtained and communicated are in accordance with what we might expect, and the council of war at Fort Donnelson bears similar testimony to its unmilitary condition. From the Northern side the intelligence has been ample, and abounds in incidents which illustrate the want of discipline; they embrace every variety of disorder, from the careless use of arms, and the independence of sentinels on duty, to attacks on officers and mutinies in regiments. And it is not

surprising that it should have been so; the private soldiers required a judicious rule, firm but temperate: how much judgment or temperance was there amongst the officers? What could be the state of a regiment in which (according to a New York paper) the major was drunk in his tent, the lieutenant-colonel was drunk on parade, and the colonel being tried for drunkenness, all at one and the same time? The paper may have added to the truth; but think how far the evil must have gone for such a tale to be told. After the first three months there were many changes among the officers, and another American paper doubts whether, out of 225 who had lately left, 25 had quitted their regiments without dishonour. Such was the judgment of their own press, and I can set nothing against it. Some few officers there were who had gone through the military college at West Point, and we may hope that there were many honourable exceptions to the general rule; but the majority earned for themselves, by ignorance and bad example, a most evil reputation in the early part of the war. When we think how much this must have checked the improvement of the army, we need not wonder that the main body did so little. A general would not be blamed for delaying an attack until his numbers were equal to the emergency; and want of discipline is a more dangerous failing, a more fatal weakness, than want of men.

I can well understand that the arms of the Federals should be excellent, their matériel of artillery magnificent, and their appearance on parade imposing; but the internal state of an army is not to be learned by seeing it march past at a review; and it seems to me that so great a change as would transform the Federal forces into a disciplined body *must* require a great space of time.

There are still other things to be weighed and considered before we blame either side for not showing us more operations on a large scale. Much of the country is still so covered with wood as to be unsuitable for great manœuvres, and the want of well-made roads would utterly prevent long marches, except in dry weather, or on routes where the railways could lend their aid. That roads should be few is only natural, considering that the population is still thin; but it is singular that in America they have been outstripped by railways, and iron tracks are now the first good communications made between rising towns. In Missouri, for instance, there are 720 miles of railway, whilst, a few years ago, there were only five macadamised roads, which led from St. Louis a few miles towards the interior; but it is on roads and not railways that a general must rely in his first invasion of an enemy's country.

As the country and the roads influenced the movements, so would the nature of the contest give a character to the earlier plans. In every civil war there is sure to be one or more districts where the inhabitants are divided in feeling between the combatants, and to establish one party in a superiority is the object of the first expeditions and encounters. Hence the operations in Western Virginia, Missouri, and Kentucky. Next in such cases is likely to come an attempt by the stronger side on the capital of the weaker, aided, if possible, by diversions on scattered points of his frontier. From this general maxim, rather than strategical plan, the first advance towards Richmond, and the expeditions of Burnside, Sherman,

and Butler have sprung. The invasion of Tennessee from Cairo, and the simultaneous advance through Kentucky from the Ohio are more nearly allied to the art of war, but still to be traced to the sympathies of the inhabitants.

Wherever the opponents meet on neutral ground, the weaker in arms and numbers cannot fail to be worsted, unless led by a superior skill which we can hardly expect to see. In the after part may come a period when strength may begin to rise out of the results of weakness; once out of reach of the formidable artillery, which is unendurable if it cannot be stormed or silenced, activity and daring may outweigh numbers — vindictive despair may compensate for inferiority of personal weapons — or the passive resistance of a united people make victory fruitless and subjugation impossible.

The Southern States are now approaching a crisis, which has only been hitherto deferred by the inability of the North to wield its weapons of offence. If the Confederacy of the South is not prepared to stand, it should not have been hasty to rise; if it cannot be patient to endure, it should not have been bold to strike. I see no reason to doubt that its spirit is true, but future events will speak for themselves: having explained to the best of my ability those which are past, my task is over; I have only to thank you for your attention, and to conclude by wishing you a better guide to the further scenes of the American War.

Friday, May 23rd, 1862.

MAJOR-GENERAL SIR RICHARD AIREY, K.C.B., Quartermaster-General, in the Chair.

THE VALUE OF A GYMNASTIC TRAINING TO THE SOLDIER.

By ARCHIBALD MACLAREN, Esq.

When it was proposed to me that I should do myself the honour of reading a paper on this subject before the members of this Institution, I for some time hesitated to do so. I hesitated because I felt the difficulty of treating a subject of this importance, and of this extent, with anything like justice in the compass of an ordinary lecture. But, on the other hand, I am so anxious to avail myself of every opportunity of bringing it with passable fairness before all who are interested in the well-being and efficiency of the soldier—I am so conscious that the members of this Institution are of all men the most capable of appreciating and of testing the merits of any scheme claiming to further this object—I am so impressed with the importance of the subject itself—I have had such ample evidence of its value, and, as I believe, I can produce such convincing proofs of the power of the system of bodily training which I advocate to accomplish the object desired—that I hastily overcame my first scruples, and have endeavoured to prepare a short paper, touching, as far as time would admit, on its chief features, feeling sure you will extend to me your indulgence, in consideration of the difficulties I must encounter in any attempt to treat a subject embracing so many details in so brief a space of time.

But before doing so, before bringing to your notice any proofs of the value of the system, before attempting to show the advantages which one form of exercise possesses over another, I would ask your attention to some remarks, perhaps not very easy to follow, on account of the brevity with which it has been necessary to treat them, on the nature of exercise; I mean exercise in its abstract sense, whether taken for amusement, recreation, or with the avowed purpose of obtaining from it, what it is found by experience to give—strength; in short, I will endeavour to show what exercise is, what it does, and how it does it.

Exercise may be briefly defined as muscular movement. Muscular, because all movements of the body are executed by the muscles. It is by the action of the muscles, separately or in concert, that our every move-

ment, great or small, from the lifting of a finger to the most powerful effort of which the human body is capable, is performed; the power of executing such movements being always in proportion to the contractility, or, in other words, to the strength, of the muscles employed, evidenced externally by their development.

Now, it is an unerring natural law, that wherever the blood, which is the source of nourishment to the entire body, is circulated in the most abundant quantity, there will be the greatest development; and, by an equally unerring law, the quantity of blood circulating through each part is chiefly regulated by its exercise. Will you allow me to repeat this passage, it is so very important? "Wherever the blood, which is the source of nourishment to the entire body, is circulated in the most abundant quantity, there will be the greatest development—and the quantity of blood circulating through each part is chiefly regulated by its exercise." In other words, the development of the body, or of any part of the body, will be in relation to its activity, because the circulation of the blood in that part is in relation to its activity. The results of this law are familiar to us all in the fact that every one of the four hundred voluntary muscles of the human body will develope, will increase in size, strength, and dexterity, exactly in proportion as it is called into action. Whatever muscles of the body are called most frequently into action, whatever muscles of the body are most frequently exercised, will be found to be proportionately the largest, the strongest, and the most dexterous. For the present purpose we will view this as the first object of exercise—to increase the power and dexterity of the voluntary muscles of the body.

But in addition to these muscles which perform the various movements which we desire, and which are placed for the most part on the external surface of the body, forming the walls of the upper and lower cavities of the trunk, and constituting the principal bulk of the limbs, there is another class, small in number, and for the most part contained within the cavities of the body, over which we can exercise little or no control—muscles chiefly employed in the processes of digestion, circulation, and respiration, and called involuntary muscles. As I have said, and as their name implies, over these we can exercise no control, but they are equally susceptible with the voluntary muscles of improvement by exercise. For, although the movements constituting the exercise are performed by the voluntary muscles, the impetus given to the circulation in these parts is shared in a greater or a less degree by the rest of the body. We are all familiar with the increased warmth and pleasurable energy felt during and for some time after exercise, where it has not been too violent or too long protracted; this is caused by the greater rapidity with which the blood is circulating throughout the body; and the involuntary muscles are also stimulated by it to activity, evidenced by the increased and energetic beating of the heart and quickened and more powerful respiration. So that, although the exercise be executed by the action of the voluntary muscles alone, yet the health and vigour and capacity of every organ of the entire body will be with them proportionately increased. And thus we may view as accomplished the second object of exercise—to strengthen and develope the all-important organs on which not health only, but life itself, depends.

But there is another advantage of the greatest importance accomplished by exercise—accomplished by the energetic action of the voluntary muscles—I mean the effect of exercise on the condition of the blood itself, from which, as I have said, the whole body receives its nourishment. In every breath we breathe, whether asleep or awake, in sickness or in health, a double process is performed within our lungs—a double process acting directly on the blood at the moment of its passage through them. First, the blood which, as I may say, has made the circuit of the body, having parted with its nourishing and revivifying properties during the first half of its journey, and returned loaded with the waste and effete particles which it has received on its backward course, meets with the air inspired, and to this air it imparts, to this air it resigns, by this air it is relieved of, the load of waste material, principally in the form of carbonic acid gas, a gas which is itself a deadly poison, and the accumulation of which in the blood is productive of innumerable evils. This is one part of the process which takes place in the lungs during the act of breathing, namely, the setting free from the blood of the impurities with which it is charged; the second part is the absorption from the newly inspired air of a relative quantity of oxygen, which is as valuable, as necessary to life, as the carbonic acid is inimical to it. Now, as every one is aware, the direct and immediate effect of exercise is to quicken respiration, and not only to quicken it, that is, to make the separate inspirations and expirations follow each other with greater rapidity, but to make each separate breath of air larger in quantity. What is the direct effect of this accelerated speed and increased volume of the air respired? The blood is more perfectly aërated, is more abundantly supplied with oxygen, more freely and effectually relieved of its carbonic acid. And more than this. The lungs are but one of several organs whose office is to relieve the blood of all matters which might prove injurious to the health of the body, and these organs are all equally stimulated to increased activity by exercise, and receive from it equal permanent benefit.

At what point have we now arrived? First, we have seen that the development of the muscular system depends upon exercise. Secondly, that the health and strength of the vital organs also depend upon exercise. Thirdly, that the purity and nutritive condition of the blood, from which the whole body is nourished, also depend upon exercise; and that these various processes all tend to produce the same results, namely, the health and strength of the body.

I have said that development is in relation to activity, and that strength is, *cæteris paribus*, in relation to development, and this is the key to all physical improvement. We have but to ascertain what part of the body is the weakest, and by giving it suitable exercise we can strengthen it. We have but to ascertain what part of the body has received the smallest share of employment, and consequently the least nourishment, and consequently again has attained the smallest development, and instant means can be taken to remedy the evil, to increase its size and capacity, to improve its conformation, and place it on an equality with the rest of the body.

These being the sure results of exercise, it becomes a matter of the gravest importance to consider what forms of exercise are in themselves the most valuable. It is here, therefore, that I would now desire to direct

your attention to the distinction between purely recreative exercise and systematised exercise or gymnastics; I mean, between exercise which is taken for the amusement, the interest, the pleasure, which some game, sport, or pastime affords, and that which is taken for the sole purpose of the training and strength which it gives. Now, although recreative exercises do undoubtedly give strength also—health and strength to both mind and body—and earnestly as I would recommend that they should have every facility provided for their practice, and should be encouraged by every available means and every suggestive expedient—still it must never be forgotten that not one of these has for its object to develope the body, to give to it, or to any part of it, health and strength. So far from the weakest parts of the body receiving special culture on account of their weakness in recreative exercises, it is just the contrary; the parts of the body chosen to execute the movements of the game are those which can do them best, those in fact which are already the strongest and most dexterous. Not one of them is sufficient to accomplish the perfect development of the body, to bring it to that point of strength, dexterity, and power of endurance to which it is capable of attaining; and to expect this from them, is to expect what they were never designed to give. To accomplish this requires exercise of another kind—exercise prepared upon a clear comprehension of what is required, and how the thing required is to be obtained. It must be exercise for its own sake, exercise for the distinct purpose of the culture of the body. And this is the place claimed by gymnastics, these are the objects which they can accomplish. While I claim for their practice, if the gymnasium be in the hands of a competent superintendent and his instructors be properly qualified men, as high and as intelligent an interest, as great amusement and pleasure, as in any purely recreative exercise, the attainment of bodily health and strength is the one thing aimed at. I claim for the system that I advocate, that, no matter what may be the state of a man's health at the time he begins his work, if he be as weak as a child in the nurse's arms, or the most powerful athlete in his regiment, the exercises of the gymnasium can be regulated to his power—can enable the weak to begin without danger, without disappointment, without any risk of failure that could wound his *amour propre*, or lower him in the eyes of his comrades, but, on the contrary, will afford him a fair starting-point from which he can daily, hourly, lesson by lesson, add to his little store of strength, until he stands abreast with his fellows. And to the powerful man it affords the opportunity of showing his strength, of sustaining his strength, of preserving it intact, serviceable and disposable at any moment for the exigencies of his profession.

I arrive now at the important question, that question to which all the foregoing is but introductory, Does this apply to the position of the soldier? To put it more directly, Do the duties of the soldier yield that abundant physical employment which ensures the full development of his bodily powers? and do the exigencies of his profession require or render valuable the possession of great physical resources?

It will be conceded that the men who fill the ranks of our army are drawn from almost every species of trade, occupation, and calling, and embrace almost every grade of physical power;—massive, powerful men

from the farm, the quarry, the forge, the warehouse and the wharf, and slight, half-formed, half-fed youths from the factory, the shop counter, the desk, and from the innumerable petty trades in which men find employment in closely populated districts. I believe it may be roundly stated that every occupation followed in this country is represented in the army; and, Gentlemen, if what I have stated regarding exercise and its results be correct—and it is founded on the clear and accepted laws which govern our growth and development—to state that every form of occupation in this country is represented in the army, is virtually to state that every form of growth and development is represented there also. (I mean of course within those limitations observed in the enlistment of recruits and subsequent medical examinations). Now, most of the occupations in which artisans and labourers are engaged give powerful and active employment to certain parts of the body, the other parts receiving comparatively little; and the inevitable result of this unequal employment is unequal development, because power is in relation to activity. The parts that have been actively employed will be shapely and strong; the inactive, neglected parts will be weak and stunted. And this will be evident to every eye that knows what proportions to look for; the nature of the employment leaves its mark upon the man for good or for evil—a sign, a seal in witness of his strength and beauty, or a brand denoting his weakness and deformity—fashions him, moulds him for shapelessness or distortion so unerringly, that to the experienced eye the nature of the craft or calling is instantly revealed; or, the occupation being known, you may tell before looking at the man the condition and the direction of his development.

This is the material out of which the soldier is to be formed; rather, let me say, these are the men to whom is to be taught the profession of arms, than which there is none more noble; there can be none so noble, since in the keeping of the soldier, confided to his care, entrusted to his guardianship, are the prosperity, the safety, the honour of the country.

In men drawn from so wide a field will be found every gradation of physical strength, the strongest and the weakest. To take the two extremes for illustration, and to begin with the man of large stature and powerful frame; how has he acquired his powerful frame? Chiefly by energetic and powerful exercise. Other things may have contributed, indeed must have contributed, such as abundant diet, and probably fresh air; but neither of these, nor both of these, nor all the other agents of health put together, will give muscular power without muscular employment. Now remove such a man suddenly from his employment, take him to the depôt to be straightened and taught to march with his head upright, his arms close in by his sides, and the trunk of his body held erect and motionless as a pillar, and what are you doing? That which is suitable and necessary to enable the man to take his place in the ranks as a soldier, but nothing whatever to sustain, far less augment, his bodily energies. The constrained position, the restricted and closely localized movements of parade and drill, all deny to the trunk of the body and the upper limbs any exercise whatever, any share whatever of that which has given them the strength which they possess, for a continuation of which they are pining, without which they must dwindle to the loss of their shape and size

and power, and the still more important loss to other parts of the body, depending for their health and activity upon the health and activity of these.

But there is another condition of large stature and rapid growth which I would desire to instance; I mean the man of large frame with little strength, the results usually of a strong and unsubduable germ of growth in the individual, which, with adequate diet and suitable and abundant exercise, produces those splendid specimens of men whom we are fain to view as the type of our race, but who, with an inadequate or irregular supply of these agents during the period of their upward growth, attain the bulk of frame, but miss the soundness of constitution and the physical energies which should accompany it. There are many of these men in the army—there must ever be many of these men in the army. We have only to think for a moment of the insufficiency of diet alone, insufficiency in quantity and quality, at a time when abundance was a necessity to either present or prospective health or strength, to know that we have got the *shell* of the man only. Sound, strong, or lasting, he cannot be, because in him we have distributed over a large surface that which is only adequate for a small one. Is it possible yet to restore him to the place he was designed to occupy, designed by the incontrovertible evidence of his stature, attained in spite of his deprivations? Is it possible to give him that soundness of constitution, energy of muscle, elasticity of action, and symmetry of form which were his by birthright? Not possible—not possible to give, after growth is completed, that which should have regulated growth itself, beginning with its beginning, adding to, proportioning, consolidating, and sustaining every cell of every fibre or tissue, as it was added to the frame: but still possible, still feasible, still a certainty, yet to recover a valuable portion of the health and strength, activity and energy of which he has been deprived; still possible to double his material well-being as a man, to double his serviceability as a soldier. At once, the first day he is recognised in the depôt as an embryo soldier, take him to the gymnasium, prepared, fitted, built for his reception and use; place him under the care of instructors, taught to administer exercise on a clearly defined and comprehensive system, a system calculated to meet the requirements of every learner, weak or strong, to meet the requirements of the whole frame of every learner, and to give to the whole frame suitable and uniform and adequate employment. Do this, and you will create within him a new growth, a new life; a growth for the rectification of all that is wrong, and strengthening of all that is weak; a life within each separate cell, straining for the recovery of that which has been neglected since his birth.

Let us take another instance. The youth who has everything to gain—slight and slim, under-sized and under-fed, who can scarcely be reckoned the raw material out of which a soldier is to be made, but who from his youth, and from that strong germ of physical power which I have learned to look upon as inherent in the frame of every Englishman, is awaiting but the stimulating, quickening, life-giving properties of judiciously regulated exercise to swell and expand into healthy, vigorous existence. What does such a youth gain in drill and parade for the development of his latent resources? He is not twenty yet; capable of receiving vast additions to his physical powers. This is the case with Oxford men, who from their childhood have been living in that state of mental and physical

employment most favourable and most directly conducive to timely development. They seldom attain to their full bodily powers before their twenty-third year. But the youth of the nature I am instancing will be found to be greatly in arrears at all points. What is there in his professional duties to supply the want? So little, so very little, in comparison with his great requirements and almost unlimited capacity for improvement; and that little so partially and so unequally administered, that even its value is reduced. For observe, he cannot attend a parade, walk to a rifle-range, cross a barrack-yard, or ascend a barrack-square, without giving employment to the muscles of his lower limbs, although such employment be altogether inadequate to produce their full development; but it is abundant in comparison to what the upper limbs and trunk receive. These must languish, these must remain relatively feeble, because they are kept without employment, and power is in relation to activity.

It is this inadequacy, this partiality of exercise employed without reference to this law, which render gymnastics or systematised exercise so valuable, for by it only can employment, suitable in nature, degree, and duration, for every part of the body, be provided—and, while the comprehension of this law teaches us how to look for partial developments, and defective and imperfect growth, it has but to be ascertained what these local wants are, what parts of the body are relatively weaker than the remainder, and such employment can be furnished as will raise any such part to the rank of the rest of the body in strength and in serviceability. And, where the entire body is below the point of power to which it should have attained, suitable employment can be furnished for every part, for the whole collectively—employment that can be increased and intensified with the advancing capacity of the learner. And it must never be forgotten that in developing a limb to its full power and perfect conformation we do that, and, except indirectly, we do nothing more; whereas a glance at the trunk of the body will show that in developing the parts of which it is composed, I might almost say constructed, so numerous are its parts, and so complex is their arrangement, we do that and a great deal more. We not only develope to their normal shape, size, and capacity the important muscles of the trunk, but at the same time, and by the same process, we bring to its perfect shape and size the framework which encases and protects those vital organs, whose health and functional power we have seen to be all important. The health of these organs, and their power of performing their functions with due completeness, are essentially dependent upon their perfect freedom; and this freedom they cannot have, if confined and restricted by the narrowness, or other deviation from the natural shape and size, of this enclosing framework; they cannot attain to their full size and power if thus fettered, and no activity on their part can do other than aggravate the evil of their confinement. In thus providing, therefore, for their freedom in functional activity by the expansion of the chamber in which they lie, we directly aid in their development, directly increase their power.

But can I prove, can I adduce any evidence, that the system of bodily training which I advocate would meet the end desired, would adjust and regulate and place under his control the entire available resources of the strong, would sustain and add to his strength and increase his professional

serviceability—that it would take up the comparatively unformed, undeveloped, and altogether negative, frame of the young recruit, and cultivate him into an energetic, active, and strong man? I have no hesitation whatever in saying that it will do both of these, and I believe I can give sufficient evidence that I do not over-estimate its power.

Many years ago I instituted in my gymnasium at Oxford a series of measurements, by which I could ascertain the state of the development of all pupils at the commencement of their instruction, and, these measurements being repeated at given intervals, I could know the rate of their advancement. The revelations made by this system of periodic measurements have been such, as to sustain me in devoting my entire energies to the completion and extension of my system of exercise. I find that to all, child or adult, weak or strong, it gives an impulse, a momentum to the development of his resources, which nothing else can give;—and which nothing can take away, because it is not a thing acquired, a mere mental or physical acquisition; it is the man altered, the man improved, the man brought nearer to the state he was designed to hold by the nature of his organization.*

But the question will naturally present itself, Would the same results be obtained from a similar system of bodily exercise by the men who fill the ranks of our Army as by the youths passing through our Universities? I think the statements which I have now to make, will satisfactorily answer this question.

The first detachment of non-commissioned officers, twelve in number, sent to me to qualify as instructors, were selected from all branches of the service. They ranged between nineteen and twenty-nine years of age—between five feet five inches and six feet in height—between nine stone two pounds and twelve stone six pounds in weight—and had seen from two to twelve years of service. I confess I felt greatly discomfited at the appearance of this detachment, so different in every physical attribute; I perceived the difficulty, the very great difficulty, of working them in the same squad at the same exercises, and the unfitness of some of them for a duty so special as the introduction of a new system of bodily training into the army—a system in which I have found it necessary to lay down as an absolute rule, that every exercise in every lesson shall be executed in its perfect form by the instructor, previous to the attempt of the learner; knowing from experience how important is example in the acquisition of all physical movements, and how widely the exercises might miss of their object if unworthily represented by an inferior instructor. But I also saw, that the detachment presented perhaps as fair a sample of the Army as it was possible to obtain in the same number of men, and that if I closely observed the results of the system upon these men, the weak and the strong, the short and the tall, the robust and the delicate, I should be furnished with a fair idea of what would be the results of the system upon the Army at large.

I therefore received the detachment just as it stood, and, following my method of periodic measurements, I carefully ascertained and registered

* A few of these results I have made known in a paper read by me at the meeting of the British Association at Oxford two years ago, and since published in "Macmillan's Magazine," Nov. 1860.—A. M.

the developments of each at the commencement of his course of instruction, and at certain intervals throughout its progress. A tabular statement* of these measurements will appear, I believe, in the forthcoming blue book, as they were furnished by me to Dr. Logan, the Inspector-General of Hospitals, with whom I have had the pleasure to be associated on the Committee appointed to consider the question of the introduction of these exercises into the Army; but I may here mention that the effects were beyond my most sanguine hopes, and equal to any precedent among the youths in those higher positions of life among whom my observations had been hitherto chiefly made. The muscular additions to the arms and shoulders and the expansion of the chest were so great as to have absolutely a ludicrous and embarrassing result, for before the fourth month several of the men could not get into their uniforms, jackets and tunics, without assistance, and when they had got them on they could not get them to meet down the middle by a hand's breadth. In a month more they could not get into them at all, and new clothing had to be procured, pending the arrival of which the men had to go to and from the gymnasium in their great coats. One of these men had gained five inches in actual girth of chest.

Now, who shall tell the value of these five inches of chest—five inches of additional space for the heart and lungs to work in? There is no computing its value, no power of computing it at all; and, before such an addition as this could be made to this part of the body, the whole frame must have received a proportionate gain. For the exercises of the system are addressed to the whole body, and to the whole body equally, and before this addition could be made to the chest every spot and point of the frame that you could touch with the tip of your finger must be improved also; every organ within the body must be proportionately strengthened.

But I tried another method of recording the results of the exercises. I had these men photographed naked to the waist shortly after the beginning of the course and again at its close; and the change in all, even in these small portraits, is very distinct, and most notably so in the youngest, a youth of nineteen, and, as I had anticipated in him, not merely in the acquisition of muscle, but in a readjustment and expansion of the osseous framework upon which the muscles are distributed.

But there was one change—the greatest of all, and to which all other changes are but means to an end, are but evidences more or less distinct that this end has been accomplished—a change which I could not record, which can never be recorded, but which was to me, and to all who had ever seen the men, most impressively evident—and that was the change in bodily activity, dexterity, presence of mind, and endurance of fatigue; a change, gentlemen, a hundredfold more impressive than anything the tape measure or the weighing chair can ever reveal.

The results upon the second detachment of instructors whom I am now qualifying are equally satisfactory, but more uniform, the men having been more specially selected.

Up to this point, gentlemen, I have spoken but of the beneficial results of exercise as affecting the man, without special reference to his profes-

* See table in Appendix.—Ed.

sional duties as a soldier; and I have done so purposely, because you will in a moment see that the power of the man and the serviceability of the soldier are inseparable conditions. Our embodied idea of energy, activity, and strength is the soldier, these qualities trained to, made subservient to, the exigencies of his profession ; and these qualities are the inevitable results, the incontrovertible results, of that system of bodily training which I advocate, because the system itself is based upon, and all its directions are in accordance with, the natural laws which govern the growth and development of the human body. Endow a man with these qualities, therefore, and you endow him with the power of overcoming all difficulties against which such qualities can be brought to bear, against all difficulties requiring strength, activity, energy, dexterity, presence of mind, tenacity, and endurance. You cannot limit a high qualification to a single use any more than you can limit the purpose to which a good coin may be applied; it will fetch its value anywhere and in anything. And so will strong muscles and sound lungs—in garrison, in camp, or on campaign, on the march, in the field, in the transport, in the hospital, on any service, in any climate.

But, although we cannot limit the use of a qualification, we can very readily give to it a special direction by special care, and make it more distinctly valuable for special purposes. And this is emphatically the case with the application of the powers acquired by gymnastic training to the duties of the professional life of the soldier. Indeed, as will be seen by the published book of the system, this is the ultimate aim and object of every exercise in it, and this is clearly inculcated and steadily kept before the learner throughout his instruction. And the last course in the system consists exclusively of the practical application to a professional use of all that has gone before, teaching the soldier how to overcome material obstacles of every form, position, and character, surmountable by walk or run or leap or vault or climb, with implements and with arms, singly and self-dependent, or with comrades rendering and receiving mutual assistance.

Therefore the question which I have advanced, "Do the exigencies of a soldier's life require or render valuable the possession of great physical resources?" I will not further answer, because the answer is apparent on the face of the question itself, and the question was only put to emphasize the importance of the subject to which it refers. I feel it would be unbecoming in me further to enlarge upon this subject before professional men, acquainted by life experience with all the forms in which the exigencies of the soldier's profession make daily, hourly claim upon his physical resources, and who know that health and strength are the essence of the soldier's power.

Nor need I repeat here, because they must be familiar to you all, the startling statistics which show the small per-centage of men who fall by the weapons of the enemy, in comparison to those who succumb to the demands made upon their bodily energies. For the one enemy in his own form which the soldier has to encounter, there are a hundred lurking around him unseen, in the form of sufferings which originate in the manifold trials of his professional life. He cannot stand the heat, or he cannot stand the cold; he cannot stand the

terrible exertion and excitement of the struggle, or he cannot stand the monotony of the camp and wearisomeness of the march; he cannot subsist on the scanty and ill-prepared rations; he cannot bear up against the broken and insufficient rest. Against his single human foe we put into his hands the most perfect weapon invented—I might almost say inventable—by man; against the other foes that lurk in his path, awaiting him at every turn, there is but one protection—to strengthen the soldier himself.

In conclusion, I would merely remark, that while this is applicable to the soldiers of every country, how much more so—with how much greater force—does it apply to our own, who have to pass from station to station over the whole world, who have to endure the extremes of every climate, from the almost arctic cold of Canada to the tropical heat of Africa and the Indies? If physical energy and constitutional strength be the essence of power in the soldiers of any other nation, they must be so with strange distinctness in those of ours, who have to exercise their profession over almost every country on the face of the globe, and to endure the hardships, the fatigues, the discomforts of them all.

In this paper I have spoken only of the physical advantages which the soldier would derive from a systematic bodily training, but its value in a moral point of view would be almost as great, as evident, and would be assured by the natural action of laws as plain as those which regulate his material improvement. I do not allude merely to the filling up healthfully, pleasurably, and profitably of his spare time—I do not allude merely to the evidence which it would set before him of how health and strength are gained, and how they are lost, and of the immeasurable advantages which the possessor of these qualities has, in every situation of life, over the man who has them not—I allude to the well-known physiological fact, that active bodily exercise has the direct effect of checking that desire for stimulants and excitements and sensuous indulgences, which sap and undermine the constitution, and waste and wear out the soldier's frame, and which arises, not so much from any physical want, or for the natural gratification of any legitimate physical desire, as from a nervous irritability and craving, that become the stronger the more they are indulged, and the strength and force of which are usually in an inverse ratio to the bodily strength and power of the individual—in an inverse ratio to his ability to indulge in them with impunity.

APPENDIX.

The Gymnasium, Oxford,
April 26th, 1861.

DEAR DR. LOGAN,—You expressed so much interest in the report which I sent you some time ago on the progress made by the men whom I am qualifying as gymnastic instructors, that I am induced to send you a second, showing the ultimate results of their course of instruction, for they return to Aldershott to-morrow.

Had I, in this first attempt to introduce gymnastic exercises into the Army, been desirous merely of producing a number of athletes, I should have requested the exchange of some of the men; but I considered that I

should be more correctly interpreting the wishes of his Royal Highness in accepting whatever men were sent to me, and thus testing the value of the system by its effects upon men of widely different degrees of physical power, stature, age, and constitution. For this reason also I have not restricted my tests to the ordinary course of measurements instituted in my school; in the first week of their instruction I had a photograph of each man taken in a position to show the state of the muscular development of the upper limbs and the general conformation of the chest; and in this, their last week, I have had these photographs re-taken, and I think you will consider the results which they manifest of sufficient importance to warrant my thus drawing your attention to them. Here, in Oxford, where I yearly receive large numbers of youths from our public schools, I have been enabled to make extended observations on the results of systematized exercise on their frames and constitutions; but I confess I was not prepared to find that men in another rank of life, whose early habits and occupations must have been essentially different, were equally capable of physical improvement.

I have arranged the names and portraits according to age, and you will see that from the youngest to the oldest, the first only in his 19th year, and the last in his 29th, and counting twelve years' service, all have made great and general improvement; those who required it the most having had the greatest gain, for evidence of which I would refer you to No. 9, originally a delicate man, now a comparatively strong one. But it is to the first on the list that I would most particularly desire to direct your attention; for, as you will see, the physical condition of this young man has been in a few months so materially changed, that, when the features are concealed, one would scarcely imagine that the photographs represented the body of the same individual. I need not say that the alteration must be great to show at all in these small portraits. Moreover, his is the temperament and the nature of body—thin, hard, and spare—that is least susceptible of change and material increase.

If, therefore, I am correct in viewing these men as fairly representing those who fill the ranks of our army, the same good which has been obtained by these may be obtained by all; and, if the case of the youngest of the detachment represents the condition of the recruit and young soldier, I think I am right in assuming that were this system of bodily training administered to them at the outset of their military service—while with some the upward growth is still going on and with all the lateral development is in full force—not only would their physical powers be doubled for every use to which they could be applied, whether for the overcoming of obstacles by strength and activity, or for the endurance of protracted exertion, fatigue, or privation, but, what you will perhaps agree with me in viewing as a greater good, this vast and permanent expansion of the chest will powerfully aid in resisting or in giving exemption from those forms of disease which specially attend the duties and habits of the soldier.

I remain, dear Dr. Logan,
Yours very faithfully,
ARCHIBALD MACLAREN.

T. G. Logan, Esq., M.D.,
Inspector-General of Hospitals.

TABULAR STATEMENT OF MEASUREMENTS OF 1ST DETACHMENT OF NON-COMMISSIONED OFFICERS SELECTED TO BE QUALIFIED AS MILITARY GYMNASTIC INSTRUCTORS.

No.	Name.	Date.	Age.	Measurements. Height.	Weight.	Fore Arm.	Upper Arm.	Girth of Chest.	Increase. Height.	Weight.	Fore Arm.	Upper Arm.	Girth of Chest.
				ft. in.	st. lbs.	ins.	ins.	ins.	ins.	lbs.	ins.	ins.	ins.
1	Sergeant Smith, 55th Foot	Sept. 11.	19	5 8½	9 2	9½	10	33					
		April 30.		5 8¾	10 1	10½	11¾	37½	¼	13	1	1¾	4½
2	„ Jackson, 49th Foot	Sept. 11.	21	5 9	10 5	10	11	34¾					
		April 30.		5 9½	11 1	11	12½	38½	½	10	1	1½	3¾
3	„ Flannigan, 41st Foot	Sept. 11.	23	5 5	9 7	10½	12	34					
		April 30.		5 5¾	10 2	11½	13½	37½	¼	9	1	1½	3½
4	„ Reilly, 18th Hussars	Sept. 11.	23	5 7½	9 13	10½	12	37					
		April 30.		5 7¾	10 8	11½	13	38½	¼	9	1½	1	1½
5	„ Tarbotton, 5th Lancers	Sept. 11.	23	5 8½	9 10	10	11	36					
		April 30.		5 8¾	10 6	10½	12	37	¼	10	¼	1	1
6	„ Steel, 32nd Foot	Sept. 11.	23	5 9½	11 3	11	12	36½					
		April 30.		5 9¾	11 12	11½	13	38½	¼	9	¼	1	2
7	„ Bartlett, R. A.	Sept. 11.	23	5 9	10 6	10¾	12	36					
		April 30.		5 9½	10 11	11	13	38½	½	5	¼	1	2½
8	„ Kearney, 10th Foot	Sept. 11.	24	5 8¾	10 8	10¾	12¾	35					
		April 30.		5 9¼	11 6	11¾	14	40	½	12	1	1¼	5
9	Corporal Sheppard, R. E.	Sept. 11.	26	5 6½	9 5	10	11½	33					
		April 30.		5 6¾	9 11½	10½	12¾	36	¼	6½	½	1¼	3
10	Sergeant Beer, R. A.	Sept. 11.	26¾	5 11¼	12 6	11½	13	41					
		April 30.		5 11¾	13 1	11¾	14	42	½	9	—	1	1
11	„ Cox, 16th Lancers	Sept. 11.	28	5 7¾	10 10	10½	12½	37					
		April 30.		5 8¼	11 9	11¼	13¾	40	½	13	1½	1½	3
12	„ Rafferty, 45th Foot	Sept. 11.	28	5 10¾	10 9	10½	13	37					
		April 30.		5 11	11 11	11¾	14	40	¼	16	1½	1	3

ARCHIBALD MACLAREN,
The Gymnasium, Oxford.

Evening Meeting.

Monday, March 3rd, 1862.

Captain E. G. FISHBOURNE, R.N., C.B. in the Chair.

ON THE PROTECTION OF THE BOTTOMS OF IRON SHIPS FROM CONCUSSIONS AND FROM FOULING.

By JOHN GRANTHAM, Esq., C.E., &c. &c.

Mr. GRANTHAM.—I think I need no better apology for appearing before you this evening, to explain the subject which I have to introduce to your notice, than will be afforded by reading a few lines from the report of the debates in the House of Commons on Friday last. They relate to this special subject, and show, I think, that on the public mind the question we have now to consider is the one which of all others is at present preventing the extension of the use of iron in the building of ships for the Navy. Lord Clarence Paget said: "The honourable Member for Birkenhead was probably better acquainted with the comparative merits of wood and iron than anybody else; but the service of mercantile vessels was a very different thing from the service of men-of-war. Our ships had to be sent to all parts of the world, and they remained abroad for three or four years. Every practical sailor knew that a vessel with a foul bottom would neither steam nor sail, and became utterly useless as a man-of-war. We had not yet got over that difficulty in iron vessels. That it would be eventually overcome he had no doubt; but as long as it existed it would be unwise for the Government suddenly to abandon the building of our smaller ships in wood. Our copper-bottomed vessels were good for two or three years without going into dock. That would not be the case with iron ships. He believed, indeed, that with iron ships we would require docks all over the world; and, upon the whole, he thought we could not do better than continue the construction of small wooden vessels."

Here the subject turned on the question of fouling.

Mr. W. Duff referred to two iron vessels which were on the South American station when he was there. There were no means of docking them on that station, and at the end of five years one of these vessels could hardly move at the rate of two knots an hour. She was one hundred and ten days on her voyage home, had to consume her own bulk-

heads for fuel, and was given up for lost; while the other ship was three months on her voyage. Until further experiments had been tried, he hoped the noble Lord would not build our vessels entirely of iron. For purely fighting purposes, iron, which would keep out shells, was no doubt desirable, and iron frigates ought to take the place of wooden line-of-battle ships; but he did not think that the day had arrived for replacing wooden by iron ships on foreign stations.

Again the whole subject seemed to turn on the question of fouling.

Sir J. Elphinstone pointed out that, if iron vessels were sent to distant stations where there were no docks, they would in course of a little time become unserviceable.

A remark was made by Mr. Bentinck; but it had reference to another point, not to the question of fouling—viz., the strength of the bottom of iron ships.

Mr. Bentinck said: "As to iron ships being stronger than wooden ships, that was true in some cases; but in others it was not so. If an iron vessel went ashore upon a sandbank, she would hang on there a long time; but if she went upon a stony or rocky shore, she would go to pieces like brown paper."

That I think is an extreme view of the case; but it evidently had reference to the facility with which iron ships are pierced by hard bodies.

Mr. Laird, speaking on the subject of docks, said "he was rather surprised, looking at the increased size of the ships now building, and the very inadequate number of graving docks, that a larger sum was not taken to remedy this state of things. There was scarcely any graving dock that could take these vessels in. At Portsmouth there was only one, and he wished to know what steps were to be taken to provide the requisite accommodation."

Mr. Corrie speaks on the same subject, especially with reference to the necessity of frequently docking iron ships.

I had the honour last year of bringing under the notice of this Institution the subject contained in the present paper. It was then however only mentioned incidentally in the course of the discussions which followed Captain Halsted's paper on Iron Ships for the Navy. It is felt that an evening devoted to this question will not be time lost, and that the paper now to be read, and the discussions that may follow, may tend to throw some light upon and clear up some of the difficulties in the way of the removal of the only remaining objection to the employment of iron ships for the Navy. All subjects of this kind must be relative; no one is sanguine enough to suppose that a ship can be rendered invulnerable to rocks, or kept under all circumstances free from the adhesion of weeds and shells; we can only attain to approximate safety, and all modern improvements are only so many steps in attaining to greater security, higher speeds, and a better adaptation generally for the requirements of ships. These relative qualities can only be measured by what has gone before, therefore the best we can claim is to have done something *better*.

Now beyond all question iron possesses qualities that render it better adapted than wood for shipbuilding, and yet we, its most sanguine advocates, have never denied that certain defects have to be removed before superiority can be claimed for it in all its features.

In my own work on Iron Ships, written about twenty years ago, and of which a second edition appeared in 1858, the following remarks occur:—

"There is one source of risk to which iron ships are more liable than timber-built ships; I allude to the effect of a blow from a hard and pointed substance, such as the fluke of an anchor or a sharp rock. These have been found to penetrate the iron plates more freely than through the planks of a timber ship, supported as they are by the ribs, which form an almost solid bed under them." Again, "The fact that iron vessels become coated in tropical climates with shells and weeds, has operated considerably against them. . . . . That the objection exists cannot be denied, and it constitutes at present the most annoying circumstance connected with iron ships."

These quotations show that these drawbacks to iron ships are not now, as some suppose, discovered for the first time: we have long known them, and have never concealed them; but, in spite of them, iron ships are fast taking the place of wooden ones.

In the first case, to meet the disadvantage of having the plates pierced, we say, multiply the bulkheads as much as possible, and make them strong enough; and we also recommend those who navigate iron ships not to go upon rocks!

In the second, we say, apply such compositions as experience shows will keep longest clean; and when your ship goes to a tropical climate, get home as quick as you can, and put her in dock and clean her; but we are obliged to admit that if iron ships are to become universal they will get on rocks, and they must also be detained in climates where they will become foul.

It will be readily supposed that those practical men who have long been engaged in iron-ship building have given these questions their anxious attention; we have long been aware that copper sheathing is the only permanent remedy known for resisting the tendency of a ship to foul; and in proposing a system by which this may be safely applied to an iron ship, a practical method of enabling them to resist concussions from hard substances has also suggested itself.

Many attempts have been made to attach copper direct to the plates by some principle of adhesion, and one of these will, I believe, be exhibited to you to-night. I tried many of these some years ago, but abandoned them all; I then suggested the plan now before you. One man actually sheathed an iron ship formerly belonging to our Government with planks, and secured them by means of an immense number of bolts put through the plates, over this he placed copper, and the vessel had made two voyages into the Pacific when I last heard of her; but as the system of bolting was in itself bad, I cannot suppose that it could have any favourable result.

Another man, however—Mr. Jordan of Liverpool—made a much more successful attempt; and as it bears on our present question in many important respects, I shall again refer to it; but before doing so I will repeat some well-known reasons why the various compositions now in use do not meet the requirements of the case, nor act as copper does in preserving the ship from fouling.

It is known that the effect produced on shell-fish and weeds by the

copper is not purely a chemical question, but must rather be called mechanical. The oxidation of the copper, by constantly reducing its outer surface, prevents substances from adhering permanently to it. This has been shown when attempts were made to arrest the oxidation by a galvanic action being given to it; but the ship then became foul; shell-fish and weeds were not thrown off, and they had time to grow, as on iron ships.

I avoid specifying or giving more than a general opinion on the various compositions that are sold as remedies for this great evil; the fullest opportunities have now for some years been given them, and let the experience thus gained speak for itself. Upwards of twenty years ago, when the evil of fouling began to be sensibly felt, iron-ship builders used a composition that was considered efficacious, but which it was soon found was very partially successful. Some that I have seen since, and which have been claimed as new, were of a similar character. I may say generally that they cannot be substitutes for copper, because their action, if any, differs so much from it; none of them present a surface that is continually changing by the process of oxidation. Some of them present a smooth surface, and this naturally will keep clean longer than a rougher surface; but none of them, so far as I know, have been able to resist for any length of time the slow encroachments of that animal and vegetable life that arrests the career of the most powerful ships.

Like many others, I have contended that some simple thing would be found to meet the case, but time has produced nothing. For many years the subject has been under the anxious consideration of our best naturalists, chemists, and practical men, and, as far as I can judge, some of our first attempts at a remedy were as good, or nearly so, as any that have succeeded them. The cry still is, let us wait and something will be found; but I believe that nothing at present but copper gives any prospect of success, and the plan here presented to you admits of the ship being coppered while it is otherwise a protection to her against concussions.

Now it is remarkable that men who have long resisted any particular improvements or discoveries, no sooner become converts, than they fall into the opposite extreme and show an undue confidence in the new system. This has been remarkably illustrated in the various stages in the progress of iron-ship building, and this evil of fouling which the long consistent advocates of this material have felt to be so serious, is now said to be of minor importance. Why, Sir, the whole question of the fitness of the general introduction of iron ships into the Navy turns on this very question. Witness, amongst other things, the frequent remarks to this effect in the debates in the House of Commons. Not that remedies for this evil are not required for the merchant service, but they appear to be essential in the Navy. For a moment consider the case of the "Warrior," in herself a great success; in such a ship a high velocity is considered an essential qualification, and, whatever advantages iron may possess, they must all be given up if the adoption of it is to result in a diminution of speed. About £80,000 has been spent on her machinery; a large amount of space has been sacrificed to it, and the coals, of which about 150 tons per diem are required to drive her at full speed; and what will be the result? Send her into the Mediterranean, the gulf of Mexico, or to India, and, if left there, in a short time her speed will be seriously reduced

and in six months her fourteen-knot speed will probably be ten, and in twelve months much less—probably seven would be her best speed. It is true when she gets into this state she may be cleaned, if you can get her into a graving dock, perhaps 1,000 miles from her station, or she may, if she can find it, be forced up into a fresh-water river, and there, after lying some time, be partially cleaned by the death of the weeds and animalculæ, whose natural element is salt water, and which cannot live in fresh. And then what follows? the ship is no sooner at sea again than the same process commences, only to be removed by resorting to a repetition of the same means. I suppose, however, that no graving docks out of Europe would receive our heavily-plated ships.

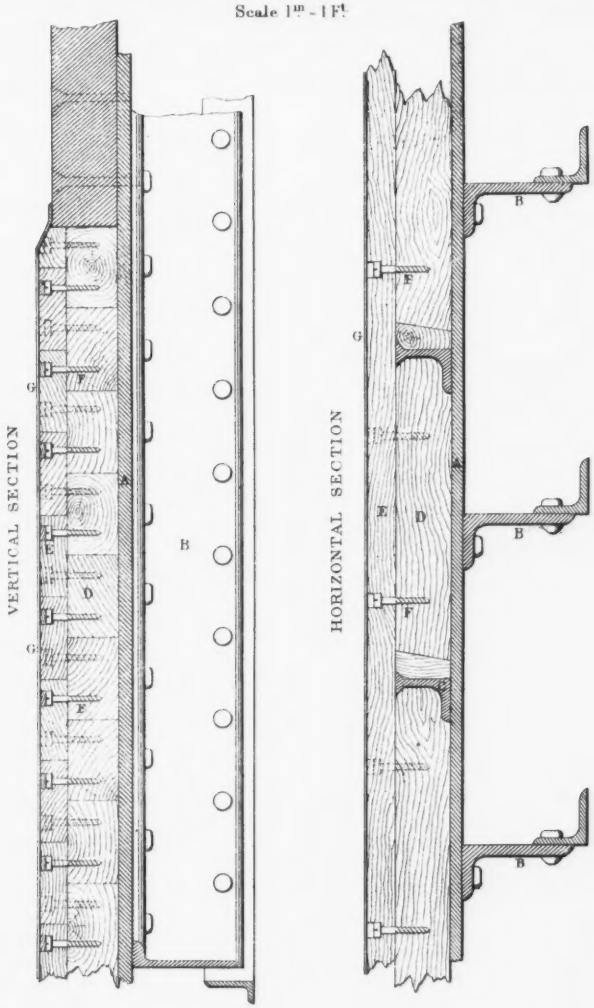
Now, that I have not overstated the case, I refer to the specimen of a moderate-sized barnacle, attached to the model of this arrangement, now in this Museum. This was one of many thousands taken from an iron ship, and is the growth probably of six or twelve months. When attached to the ship in its live state, a fish about as long as one's finger projects from every shell, causing a still more formidable obstruction.

But the case may be illustrated by well-known facts that occur in this climate, where shells seldom attach themselves, but which is due to weeds only, with a certain amount of roughness that rises in salt water upon ordinary paint. Every iron vessel for the first month after leaving the graving dock and having the plates cleaned, goes better than she does subsequently. This has been accurately tested by the new vessels belonging to the City of Dublin Steam Packet Company, which carry the mails from Holyhead to Kingstown. In the summer time, in about two months after leaving the graving dock, their speed uniformly falls off so as to increase the length of the passage ten to fifteen minutes, or equal to about half a mile to one mile an hour. After the first two or three months the retarding process in this country goes on slowly, but where shells attach themselves the contrary is the case. From these facts I am led to the conviction, which I have frequently heard expressed by others, viz., that in some cases, even in this country, it might be worth while to use copper for iron ships, should my plan prove successful. As the voyages of iron ships in the merchant service are extended, the evil is being increasingly felt. Large sums have been expended in Liverpool on the most splendid graving docks in the world, but, owing to the necessity of constantly docking the numerous large iron steamers now owned in that port, a much greater expenditure has become necessary to keep pace with the demand.

Having, I trust, shown some grounds for supposing that copper sheathing would be desirable if it could be applied, I now ask your attention to the drawings, and you will see that while the first object sought was a remedy for fouling, the same system supplies a very effectual protection against concussions, an advantage that must to some extent satisfy the requirements even of the strongest opponents to iron ships for the Navy. It will be seen that I commence by attaching frames to the outside of the vessel to run up to the light water-line, or to the armour-plates in large plate-clad ships. These frames are rolled like common angle iron, except that the outside edge is made of a wedge form, or flanged, as shown in the drawings; they are riveted to the ship in the usual manner. Between these is driven a timber planking, which becomes firmly wedged;

GRANTHAM'S SHEATHING FOR IRON SHIPS.

Scale 1^{in} - 1 Ft.



A . *Section of Side Plates*
B . *Inside Frames*
C . *Outside Frames*
D . *Inner Planks*
E . *Outer Planks*
F . *Brass Screw Bolts*
G *Copper Sheathing*

J.R.Jobbins

and being set in with suitable compositions, and then caulked, forms a solid bed. This would be made from refuse timber cut from the wood used in the other parts of the ship. The whole being then dubbed even with the ribs, and again coated, another sheathing is attached by brass screws. I have made the inner one for large ships four inches thick, and the outer one two inches. The copper sheathing is then attached in the usual way.

Thus a firm substantial bed is prepared for the copper, all metallic contact is avoided, and great additional protection is given to the bottom of the vessel. I will endeavour now to anticipate and reply to the objections that may be used against this system.

1st. That it will be expensive;

2nd. That it will add to the weight of the vessel;

3rd. That it will injure the iron plates;

4th. That the timber work will become loose when the vessel strains.

There may be others which may be suggested during the discussions that I hope will follow the reading of this paper, and therefore I will deal with those I have named as briefly as possible. In all these discussions I take the "Warrior" as the vessel to which allusions and comparisons will be made, being most deservedly greatly in advance of all other ships in public opinion.

1st. As regards the expense. I estimate the timber, labour, screws, and coating at less than £4,000, if put on when the ship is building, on a ship valued at £350,000. The copper is not included. I claim against this, in making a ship of equal safety, a saving of 200 tons of iron, which, at £20 per ton, equals £4,000. But by far the largest set-off is to be found in the saving of steam-power, and for foreign service, I set this down in the "Warrior" at 500 horses, upon the average of a three years' cruise in warm climates, or 200 horses in the home service; or, what is more important still, that the vessel shall, if kept clean, at all times maintain her proper speed.

2nd. If the comparison is to be fairly carried out, the increase of weight will be very little. I claim a saving of 200 tons of iron, and the timber will weigh 280 tons, a difference of 80 tons in a vessel displacing 8,000 to 9,000 tons.

3rd. I deny that it will injure the plates; on the contrary, I assert that it will be a great protection to them, for being once well painted, the sheathing will effectually protect the paint, and while this remains unbroken, there is no fear of corrosion. There being no bolts to work loose, and no metallic contact, there is abundant evidence to show that the plates of iron ships, under such circumstances, will be entirely free from injury.

In some respects the iron-clad ships, as hitherto constructed, are much more unfavourably placed, a large portion of the woodwork which is used as a backing for the armour plates is below the water-line, having a 1,000 tons more or less of weight outside of it, suspended by bolts about two feet long running through the timber; and iron bolts that will loosen, and in time admit water, a defect that cannot take place with the sheathing now proposed—First, because there are no bolts; and secondly, instead of having a power tending to loosen it, there will be a pressure

of water equal to the weight of the ship, tending to make it cling to her sides and bottom, a power that no ordinary means could overcome.

I have heard it asserted that injury to the plates may go on unobserved beneath the woodwork. In the first place, the probability of such injury is very remote; at the worst the water can only penetrate to the plates and there remain quiet, and even there the coating will arrest its progress; but supposing further the plates to have no protection, what is to be apprehended? the water is at once deprived of its oxygen, an infinitely small amount of corrosion takes place, and then all further mischief ceases. If there were a constant stream or jet of water, damage might occur: but this would be impossible; it could at the worst only penetrate, and there remain at rest. Such alarms as these are only a repetition of what was experienced when iron ships first were used on salt water. It was then confidently asserted that they could not withstand the corrosion, but must soon perish. We now find that iron ships, well protected, are very durable.

But I have alluded to other evidence, viz. the vessels built by Mr. Jordan, as proving that iron in contact with wood sheathing and copper, though very unfavourably placed, has stood well for ten years.

Mr. Jordan's vessels were built with angle-iron frames and several plate ribbon-pieces, having planks secured by iron bolts outside all. These ships were coppered, and were in the East Indies since they were built in 1851; one of 400 tons was lost about two years ago, and one of 780 tons is still at work. As regards the plates and ribs, both vessels are said to have been in excellent condition, though exposed to very severe trials. The iron bolts which approach nearly to the copper have suffered as might be expected, and as would have been the case to a certain extent had there been no copper. The owner, a man of great experience, declares in a letter lately written to me that he would never build on any other system. I will quote a few of his remarks. Of the vessel that was lost, he said "that the bolts were to a considerable extent affected, although no other part of the iron framework was so. At the same time, it must be remembered that these bolts had been fully eight years in use, and were still strong enough to do their work. There was the utmost harmony between the wood and the iron; no straining was ever apparent, and consequently not the slightest deviation in the sheer or form of the vessel. With all the strength of iron, they had all the advantages of wooden ships—no fouling, for they were always coppered."

4th. The last objection which I have anticipated is, that the timber will work loose. Those who have raised this objection can surely not have reflected on what they were saying. Observe the drawing, and it will be seen that the means for securing the planks are much better than the ordinary means used for attaching them to a wooden ship; in this sheathing the planks are wedged most powerfully at very short intervals between frames, which themselves are riveted to plates that are perfectly unyielding in the direction in which the seams could open. Should any yielding take place, it can only arise from the plates cracking or the seams opening, and we know this to be last extremity of an iron ship. In fact, in a sound vessel such motion is impossible. But there is another action found in all ships—viz., the bending of the whole fabric when

working in a heavy sea. I have endeavoured to reduce the amount of this to figures, for in no other way could I estimate it, the movement on each joint being inappreciably small.

I do not know whether the lateral motion of the "Warrior" has been ascertained; but I have assumed it to be four inches in her entire length, in which case I make the average opening at the outer edge of each seam in the lengthways of the ship to be about the 17,000th part of an inch, or the 70th part of the thickness of an ordinary sheet of writing-paper, and the inner edge of the seam to be absolutely nothing but what may be allowed for in the positive direct stretching of the plate between each frame at every motion of the ship.

No one for a moment will doubt that the elasticity of the timber will much more than compensate for these small movements; and it may here be well to consider how this principle acts in every timber ship, and is essential to its safety—its very existence depends on the power in the timber and oakum of its seams to expand and contract; for, suppose they had not that property, but in that respect were like lead, which can be compressed, but will not expand again, having little or no elasticity, it is probable such a ship would founder in the first gale. May I not claim in this argument some benefit from a principle which is the sole dependence of every ship made of timber?

In the matter of repairs, it may be asked, Can the wood-work be easily replaced should part of it be damaged? To this I may reply that I believe it will be perfectly easy; the inner plank may be set fast by a double wedge at any part of the vessel without disturbing the rest.

I have now very briefly to ask your attention to this system in its action, as a buffer in case of collision with hard bodies. That it will so act is self-evident: externally it will endure whatever ordinary planks will, internally it will tend to spread the effect of the blow over a larger space; it will likewise interpose an elastic substance, which, in itself, will materially lessen the effect of the direct contact with a rock or other hard body. It may be a question worth considering whether the outer plank should not be stronger than I have shown it in the flat of the floor, and in those parts where contact with rocks is most to be apprehended.

In closing this paper I very reluctantly turn to some personal considerations. I will not venture to predict what judgment will here be passed on my remarks; I can only state what I know, viz., that this plan was described to gentlemen connected with the Admiralty about ten years ago. It was shown to Sir Baldwin Walker about three years ago, it has since been strongly recommended for adoption by the Plate Committee, and has been noticed by several scientific journals, in all cases favourably. It has also received the written and verbal approval of men whose opinions would always carry weight; but to this time no attempt has been made to test its qualities. The trial of it or any corresponding plan cannot be made in a day; it will take years before it can be fairly tested. Now, supposing a trial had been made in the year 1852, when I first made it known, and it had met with approval, I believe not a single wooden gun-boat would have been built for the Russian war, but that all would have been of iron; or, if Sir Baldwin Walker had recommended a trial three years ago, and it had succeeded, we should in all our new iron ships have

had a system on which dependence could be placed for the removal of the only drawbacks to the entire adoption of iron ships for the Navy.

The unfair question is put to me, Where are your examples, on what ships has it been tried? I ask, Who is likely to try it if the Government will not, for who has so large a stake in it? Can an individual try it? It has already cost me nearly 500*l.* in the mere introduction of it to notice. Can I be expected to do more? Its advantages cannot be fully appreciated in small vessels, though it is applicable to all; its principal recommendation is for large ones, and such vessels involve large sums; and when I request that a trial may be made, I ask for no great sacrifice or risk in making it. It could not destroy the usefulness of the ship, even though it might not have all the advantages which I propose. Is it, therefore, too much to hope that such a ship should be designed? and I have no hesitation in predicting that, while having all the advantages of a timber-built ship in its power to resist concussion on rocks and fouling, so that it may be sent on a foreign station for three or four years without being docked, it will be superior in strength, of greater internal capacity, more free from leakage and other inconveniences, will sail faster because of less weight, and will cost less money both in building and keeping in repair. Such a trial, if successful, will remove the greatest objection now affecting the progress of iron ships, to the great benefit of the Government and the merchant service of this country.

R. Mallet, Esq., C.E., F.R.S.—The honour of having been asked to make a few remarks upon the paper which has just been read has, no doubt, been done me from the fact that several years since I myself made some researches on the subject of the corrosion and the fouling of iron, which have been published in four different Reports by the British Association for the Advancement of Science in the years 1839-41-43 and 49; and although not an iron-ship builder, yet having, as a civil and mechanical engineer, and for several years the active partner of an engineering firm, been familiar all my life with the practical applications of iron, and especially with its uses in the form of structural works of plate and angle iron, &c., &c., often as much exposed to corrosion as iron ships, so I am enabled to form a practical judgment on the subject brought to-night before the Royal United Service Institution. The importance of the subject itself, as Mr. Grantham has stated, I think it would be difficult to overrate; for, highly important as the corrosion and fouling of iron ships has been at all times to the mercantile marine in a money sense, it becomes of far more vital importance now that iron ships are certain to be applied for war purposes; for if it be a fact that a war ship sent to sea, after some six or eight weeks loses a mile an hour of her speed from alteration of the surface of her immense hull, or, as we may call it, from fouling,—if a vessel so circumstanced be caught by a clean ship of the enemy that has got the mile an hour still, the former is taken at a disadvantage which nothing can make up for, and so the mere state of her surface determines whether she can keep the seas or not. Hence this question of fouling has become a national one.

There are three aspects or three directions in which perhaps it will be well to make a few remarks in opening the discussion on this paper. The subject has its bearings of a directly chemical or physical character as respects corrosion and as respects fouling, and it has a practical character

as regards construction, that is to say, in what way, and to what extent principles determined by the chemist and physicist, can be practically carried out by the shipbuilder.

As respects the first, it will be perhaps advantageous if I very briefly lead back the attention of those who may not perhaps at all have considered the effects of corrosion and fouling, to a few of the fundamental facts of the subject, ascertained by myself principally, I may say; indeed, I hope I shall not be guilty of any immodesty were I to say altogether; for, so far as my knowledge goes, those four reports of mine up to this present embrace almost the whole of the scientific literature that exists on the subject of the corrosion and fouling of iron ships, and of iron generally.

Iron is only acted upon in the way of corrosion by water, whether it be fresh or salt, that also contains air in combination. All the water we find in nature contains a certain quantity of dissolved air, and the air it does contain—combined in the same way that we find the carbonic acid is in a bottle of soda-water—possesses a larger proportion of oxygen than exists in the air we breathe, *i.e.*, in the atmosphere. If a piece of iron be placed in water from which this combined air has been exhausted, whether the water be salt or fresh, at the ordinary temperature, no corrosion takes place; but if it be exposed to the action of water with this combined air, or air and water together in any other way, or to each alternately, then corrosion does take place; and up to the present hour science has failed to devise any means by which that corrosive action shall be completely arrested. All the various devices of coating with other metals, such as with zinc, usually called galvanising, are found to be perfectly nugatory, under the above circumstances of exposure and constant moisture. Even in perfectly pure fresh water, galvanising—coating the surface with zinc—is a palliative of corrosion and no more. In sea water it is entirely useless, and as applied to iron ships it would be absolutely hurtful, because, independent of any ill effects upon the toughness of the iron, one of the effects of any partial removal of the thin surface coating of zinc is that a thin coating of carbonate of lime is rapidly deposited upon that which remains, and upon that excessively thin bed of lime fouling takes place immediately—plants and animals readily attach themselves to it.

I do not despair, however, of science hereafter being enabled to make an iron ship as invulnerable to corrosion as if it were a piece of platina. I may just illustrate the conceivability of this by repeating a very simple experiment, first due to Professor Schoenbein of Basle, the discoverer of what is called the passivity of iron. Here are two pieces of common sheet iron, and a piece of platina. Here is an acid which is capable of rapidly corroding and even dissolving a piece of iron in its ordinary condition when plunged in it directly: this acid does not act on platina at all. If, however, in place of putting the piece of iron into the acid directly, in which case it would instantly begin to be acted upon, I touch it first with the piece of platina, and immerse the two together, and then withdraw the platina, the iron remains in the acid in a perfectly passive condition; the acid, which is capable of dissolving the whole piece of iron in a very few minutes, does not now act upon it at all, it remains as passive and as incorrodible as does the platina itself. Further, if I now take another piece of iron which has not been touched by the platina, and touch it with the piece which has

been already touched and immersed, it will be found that the latter piece of iron is now in the condition to bring another piece of iron into the same condition with itself, and so in its turn this second piece would not be acted upon; and so we might go on for ever. But if I put a piece of iron which has not been touched by the platina, or by another piece of iron so touched, into the acid, it will be acted upon directly; and if I touch it now with the platina while in the acid or withdrawn from it, this will not now prevent its being corroded, nor arrest the corrosion that has commenced. This little experiment suffices to show that iron, one of the most singular bodies amongst all the elements with which we are acquainted, marvellously endowed with properties fitting it for the uses of man, has yet unseen and undiscovered properties, such as those Bacon talked of long ago, when he said nature still containeth secrets more marvellous and potent than the wit of man hath yet conceived, much less discovered. It indicates the possibility that iron still contains secrets within it that may enable it to be made into an iron ship incorrodible in water, although without any external protection whatever. Indeed, did the passivity of iron extend to the chlorine compounds, as it does so far as is yet known only to the oxygen compounds, the end might be at once accomplished. By experiments carried on in Kingstown Harbour and in various other places upon the actual rate of corrosion of exposed surfaces, say a square foot of iron, for lengthened periods of three or four years, I have ascertained the rate of corrosion for iron, cast, wrought, and steel, from various makers, of different qualities, in various conditions, and in various waters, such as fresh and salt, and each both pure and foul by sewage, &c.; and I may state as one result of these experiments that the rate of corrosion for wrought iron in clear sea water—I am now talking of average iron, such as is used for ordinary ship building—would be such that, corroded on one surface only, six-tenths of an inch in depth would be taken away in a century. That is the rate at which an iron ship in sea water will corrode if not protected by paint or anything else. If protected by certain varnishes or coatings, the progress of corrosion may be enormously retarded.

The CHAIRMAN.—Six-tenths of an inch in depth?

Mr. MALLET.—Yes; six-tenths of an inch in depth in a century. That is to say, if the plates were six-tenths of an inch in thickness, and acted upon on one side only, the iron would be all gone in a century. This supposes that corrosion takes place uniformly and alike all over the surface; but that condition does not hold as respects the surface of an iron ship; there are parts where the action is much more rapid than at others, and round the rivet seams corrosion takes place, *cæteris paribus*, much more rapidly than anywhere else, from the rivets being harder owing to the process of closing, than the rest of the plate, and hence slightly electro-negative to the plates of the ship, or in the like relation to them as a piece of copper. It was long ago ascertained by Professor Edmund Davy, nephew of the celebrated Sir Humphry, that iron possesses the property of being protected, by zinc attached to it in mass, in the same way that Sir Humphry Davy showed years before that copper sheathing could be protected by zinc protectors. I ascertained that the hull of an iron ship could be protected to a very great extent from that universal corrosion which takes place, by the attachment in mass of a surface of zinc, only

extending to $\frac{1}{120}$th of surface of the exposed iron. But that will not stop such corrosion of an iron ship as goes on close to where the wash of the paddle-wheels affects her sides, nor near the bows, and other parts where the air and water are constantly agitated and renewed in contact with the iron, and fresh surfaces of the latter constantly exposed by the washing away of the rust already formed. The moment you produce protection with zinc, however, you get a deposit upon the surface of the iron of carbonate of lime in crystals—calcspar, in fact, in the ordinary rhombic form—produced by decomposition of the salts of lime in the sea water; and so the groundwork for fouling is at once laid, and it increases then at an enormous rate. I further ascertained that if the rate of corrosion of iron in an iron ship—the iron plates alone being exposed to sea water, be represented by a number equal to 8—then, if exposed in contact with copper, such as copper sheathing, in the proportion of two to three, that is to say, three square feet of iron to two square feet of copper, in that case the rate of corrosion will be increased in the ratio of 11 to 8, the iron corroding alone at the rate of 8, but at the increased rate of 11 if it be in contact with two-thirds of its own surface of copper. But I ascertained a further fact, which is an important one. Ordinary gun-metal, such as is used for the screws of our propellers (alloys of copper with 8, 10, or 12 per cent of tin), possesses the power of increasing the corrosion of wrought iron enormously more than pure copper itself, so much so that if the three square feet of iron we were talking of were in contact with two square feet of gun-metal, the rate of corrosion is increased, not from 8 up to 11, but from 8 to 19. In connection with this fact I may observe that I have seen it stated that a great number of the iron ships now being sent to sea, or in preparation for sea, by the Admiralty, are fitted with gun-metal propellers. If such be the fact, anything more injudicious or more uselessly destructive to the iron of an iron ship can scarcely be conceived, nor anything more unnecessary. Every marine-engine maker knows perfectly well that cast-iron propellers, or wrought-iron propellers, may be made perfectly safe, weight for weight, with those of gun-metal. It is hard to see, therefore, why this material, that costs about 2*s.* a pound, should continue to be used, where a material which costs about 3½*d.* or 4*d.* a pound ought to be used instead; the dearer material being positively mischievous to the iron ship as well as to the screw-bearings, &c. I also ascertained that among the conceivable alloys of copper and zinc with which an iron ship might be covered, was one closely approaching to the alloy known as Muntz's metal, but not identical with it. This was an alloy of four atoms of copper to one of zinc, very nearly the composition formerly known as Dutch brass. It is a remarkable fact that the galvanic action on iron in sea water of this particular alloy is almost *nil.* A vessel coated with such an alloy, the surfaces being in the proportion of 3 to 2 as before, the rate of corrosion of the iron is only accelerated in the proportion of 9½ to 8; the iron is hence very little worse than if not in contact with any electro-negative metal at all. So far as the chemical properties of this alloy are concerned, it might be applied directly, therefore, to sheathing an iron ship; but any attempt at coating an iron ship directly with any metal sheathing is quite out of the question. The mechanical difficulties are insuperable; you cannot attach sheathing firmly

to the skin of an iron ship in any way, but you injure the strength and diminish the safety of the ship enormously. There is another class of facts to which I may briefly refer. The rate of corrosion of iron in sea water greatly depends, other things being the same, upon the quality of the iron; I do not mean the quality of the iron in the sense in which we usually apply the word in the market, namely, the very best iron as regards toughness and strength. Here is a fact, ascertained by several years' exposure of large surfaces, and therefore reliable,—that an equal surface of the hull of a ship built of the common plates known in commerce as "boat plates"—the worst class, in fact, of Staffordshire or Yorkshire plates—will corrode in a given time at the rate of 36, while an equal surface if made of the very best plates of cold-blast South Wales iron will corrode only at the rate of about 8½ to 9; and that if the plates are of very highly-wrought iron worked over and over again, such as faggoted scraped iron when rolled into plates, or Low Moor or Bowling iron, then the rate of corrosion will be only 2½ in the same time for equal surfaces. It is hence apparent how much is lost in durability and in freedom from corrosion and fouling as well as in strength, by the too prevalent use of inferior qualities of iron for shipbuilding. I will now drop the question of corrosion and come to that of fouling. The two, however, are inseparably connected, and for this reason, that if it were possible to get the hull of an iron ship into a condition that it would not corrode at all, there would no longer be any difficulty about preventing it from fouling at all. It was years ago ascertained by Prinsep of the India Service—

Captain HALSTED, R.N.—Which of them?—because there were several brothers.

Mr. MALLET.—James; he was attached to the Calcutta mint. He ascertained the fact that, if you oil or coat a surface of iron with any greasy varnish or with any shiny material, such as the native Sylhet varnish of India, or even with common drying oil—so long as a vestige of such a coating remains upon the surface, none of the lower forms of animal life attach themselves to it. The cause is apparently a purely mechanical one. The surface is so smooth that the animal is not able to attach himself—the smallest wash of the water washes him off. But whatever be the cause, if we could get that sort of greasy material or any varnish to stick to iron permanently, we could prevent the fouling; but no coating has ever yet been devised that will accomplish this. Innumerable coating compositions have been proposed. I have myself a list, made for me some months ago, of about seventy patents that have been taken out, since the date of my British Association Report of 1843, of different nostrums for preventing the fouling of iron ships. They are all failures; not one of them has answered, not even excluding my own, which was the origin and predecessor of them all. And I may mention further: there is not one of these patent compositions that is not simply ringing the changes upon what was originally proposed by myself. In 1843 Mr. William Fairbairn and I patented a mode of preventing the fouling of iron ships. It was based on lengthened observations I had made as to what were the conditions under which animal and vegetable life attach themselves to iron ships, and what were the conditions that would be

disadvantageous to both. My researches were conducted upon many of the lower forms of marine animal life; and I was then enabled, by living on the seashore, to carry them out with the necessary accuracy and facility. I experimented on oysters, sea-anemones, mytilus, balanus, lepas, patella, and several other forms of lower marine life, besides vegetable marine forms —such as fuci, confervæ, byssus, &c. I found this curious fact with respect to these lower molluscous animals: that the soluble poisons, provided these creatures are very slowly accustomed to them, do not seem in any serious degree to affect them. I had some of these animals in glass jars for two or three years, with constantly renewed aëration of the sea water. At stated intervals a few drops of some soluble poison—for example, sulphate of copper—were dropped into some of the jars. At last I had oysters living in apparent health in a solution of sulphate of copper, which, if any one of us were to drink half an inch deep out of the glass, would have poisoned us, or produced vomiting. The animals became so thoroughly impregnated with copper, that, if you thrust a common penknife into one of them, and let it remain in his body a short time, the blade came out coated with copper. The oysters themselves did not seem particularly annoyed for lengthened periods, provided the process was conducted exceedingly gradually; they all, however, contracted in bulk, and died when the poison reached a certain amount of concentration. If you were to put an ordinary oyster, not accustomed to these bad habits of poisonous dram-drinking, suddenly into the same coppery water, it would die within a very few hours. The facts are analogous with the well-known powers of passive endurance of all the lower forms of life. The same, however, does not hold with poisons of an insoluble, or, rather, difficultly soluble, character, put in a solid but finely-divided state in contact with such animals. An oyster or sea-anemone put into a jar of sea water, into which were dropped a very few grains in fine *powder* of—say, realgar or sulphuret of arsenic, and stirred up, is sure to be deprived of life; it could not exist under such circumstances many hours. The solid grains of the insoluble poison appear to be brought into the fine cells of the branchiæ—such as the beard of the oyster—and he has not the power of eliminating them, and the animal is poisoned, by the irritating contact .probably. Whether that is the explanation, I am not naturalist enough to know; but I can vouch for the facts. My method, which Fairbairn and I patented, was based upon these. It consisted in coating the iron plates, after they had been thoroughly well heated by lighting coke fires under the bottom of the ship in dock, with boiled coal-tar chiefly, and on that was laid a slowly soluble varnish, a sort of metallic soap, containing difficultly-soluble poisonous matter. It was mainly formed of common bright varnish, coal-pitch, soft soap, and the poisonous matters, several of which were proposed; but the one which I advised as best was "realgar," or sulphuret of arsenic. I went to Liverpool to see the iron-ship builders, and, amongst others, the late Mr. Laird, with the view to get them to adopt my method. At that time the ship-builders, one and all, said, "Oh, iron ships do not foul at all, and as to corrosion they will last for ever; but in any case" (one of them told me) "we do not want your method, we have some of our own that will do as well." A few months afterwards I found that a vessel had actually been coated at Liverpool. I succeeded in obtaining some of the

coating, and I found that it consisted of bright varnish, tallow, flowers of sulphur, and white arsenic—that is to say, it was precisely the four ingredients of which my patent consisted, only combined in another shape. All similar compositions that are now used, and which have the best reputation, consist of partially insoluble salts, either of copper or arsenic, or of both, mixed generally with a lot of nostrums which are of no use whatever. They are at best mere palliatives, for it is a fact that they all do foul, after a time longer or shorter, over the whole surface. The stuff gets stripped off by the washing of the water, or accidentally, and as soon as that takes place the remaining portion begins to get coated with a thin film of carbonate of lime, deposited from the lime in the sea water; and the moment that deposit takes place the surface becomes a fit nidus for the lower marine animals and vegetables, and then fouling goes on. We therefore come to this conclusion, that some better method is wanted for the protection of iron ships than is afforded by any chemico-mechanical method of coating yet proposed. Now, I would make one or two remarks of a purely practical character upon what Mr. Grantham has brought before us. To prevent any misapprehension, I wish to state that I have no personal interest in Mr. Grantham or his patent, direct or indirect; I stand here by invitation of this body, to which I have the honour to belong, simply to state, for the information of those around me and for the good of our common fatherland, whatever knowledge I have acquired applicable to the subject. Mr. Grantham's method amounts to this: we must all admit that if we could put an iron ship into a water-tight wooden saucer of her own form, and let her go to sea in that wooden casing, corrosion or fouling could not take place on her bottom; whatever happened must happen to the wood. The question therefore is, can you make a water-tight wooden saucer round an iron ship? Mr. Grantham proposes to do so, and, for anything I see to the contrary, I think he can succeed. His method is this: he spaces over the skin of the ship a number of dovetailed ribs of iron riveted to the skin, and between these he drives in, and caulks water-tight pieces of wood; the dovetails hold them on without piercing the skin anywhere, and the caulking makes the wood skin water-tight; over all this he places what other metallic sheathing seems good to him. I conceive there can be no possible doubt that pieces of wood may be driven into dovetailed recesses of that sort, with no more skill than that of ordinary shipwright work, so as to make them practically water-tight. When such a wooden surface is coated over with another of planking, properly secured with felt or tarred paper between, and also caulked, I can scarcely conceive the possibility, while the hull remains sound, of water finding its way inside. But if the sea water should find its way in, the amount of corrosion that could take place, unless there were a stream of water in and out so as constantly to renew the agents of corrosion, would be next to nothing. I have already shown you that if a piece of iron be put into water already robbed of combined air, or if you exclude the air from it, it will not corrode at all. Therefore, if water should get in and lodge behind any one of these blocks of wood, unless it be perpetually renewed by a stream in and a stream out, the water that has got in there will, after a short time, have next to no power in the way of corrosion. I understand from Mr. Grantham that the outer planking will be secured by brass screws.

Mr. GRANTHAM.—And the seams would be caulked as well.

Mr. MALLET.—So I heard; but it appears to me that if these inner blocks were fitted and driven in dry with a reasonable degree of accurate workmanship, they would become water-tight without any caulking whatever. This first coat may be sheeted with brown paper or felt under the planking, and then the planking applied and that caulked. I would then ask, is there any objection to putting on the outer planking with wood trenails in place of with brass screws, as here shown, for in that case there would be absolutely no metallic contact of any sort between the copper or other sheathing and the skin of the ship.

Mr. GRANTHAM.—There would be no metallic contact.

Mr. MALLET.—In that case I take it that the copper would produce no effect on the ship. The copper would itself be exposed to the action of the sea, and would be in the condition of the copper of an ordinary wooden ship. Let us now suppose that the ship grounds, or rides over her own anchor, and tears a large piece of the wood coatings off her bottom. It would have to be a very heavy grind, indeed, to strip off the inner blocks, because every block supports every other, and, therefore, you would have to break off many of the rib irons in order to dislodge any of the blocks. But suppose several of them were broken off, and exposure made down to the skin of the ship, I make no doubt but that then the exposed portion of the skin of the ship would corrode much more rapidly than if there were no copper present because there would then be metallic contact between the copper and the exposed portion of the vessel, made good by the sea water. But then comes the question, *how much greater* that would be. I have mentioned the fact that iron and copper, being in the ratio of 2 to 3, the increased rate of corrosion is in the ratio of 11 to 8. Now, something more than that would be the increased rate at which corrosion would take place in the case supposed. I would merely say this much further, that there would certainly be no such amount of corrosion as to endanger the safety of the ship at sea before she could get home, or into some port where the accident could be repaired. I may mention, in explanation to such chemists as may be present, that in sea water, after exposure for considerable periods of time, the rate of corrosion of iron in presence of copper, or other electro-negative metals, does not follow the law of voltaic equivalents. It may appear strange that copper and iron put together into sea water should corrode in the ratio of 11 to 8, and not in the ratio of the voltaic equivalents. The fact is, however, that the surfaces of both metals when left to themselves in sea water get coated more or less with various insoluble sulphates, and other salts and oxides, derived both from the iron and from the sea water, which alter altogether the rate of corrosion that would otherwise take place were chemical action quite unimpeded. One or two other thoughts of a practical character occur to me. It would appear, with respect to these inner blocks, that there are some woods of which they ought to be, and some of which they ought not. I am quite clear that they ought not to be of pine wood. Pine wood is capable of getting rapidly into a condition of softening and incipent decay on its surface; in that state it rapidly decomposes the sulphates present in sea water, reducing them to sulphurets, which are again decomposed by the iron, and powerfully increase corrosion. Such very soft woods, unless

resinous or thoroughly impregnated with creosote, ought not to be adopted. Oak I object to, because, as every one knows, it rapidly acts on iron in contact with it, getting black and hard. It appears to me that a tough timber, elastic, and tolerably hard, would be the right thing. In fact, I doubt if anything better may be found than refuse teak out of the yards, or perhaps Honduras mahogany. For the outside sheathing it does not matter what timber is used, because it only touches the edges of the dovetail ribs. If this sheathing were made of fir these edges might be exposed to a very limited extent to the objectionable action of the incipient decay of pine timber. Therefore, I think it would be found advisable to put a little more iron into this part (pointing to the dovetail heads of the ribs) and so allow for that. Then, the question comes, what effect would be produced upon the inner blocks by the working of the ship. Having given that point some consideration, I doubt that there would be any objectionable effect produced. An iron ship works in more ways than one. At sea every ship vertically works up and down; it also twists. In wooden ships nothing could be more remarkable than the extent of the latter movement. I recollect reading of some old ship of Collingwood's, the stern of which, when she rolled, tumbled over 8 or 9 inches on each side from the looseness of the framing. That is the sort of motion which would be most likely to dislodge these blocks—not by any single motion, because, if you suppose the "Warrior" twisting even 8 or 9 inches, the effect of any one such movement on any block would be perfectly imperceptible, but, if that sort of working were continuous, it would be difficult to say how far it might result in gradually loosening the timber at last. This is a conceivable possibility, but I do not adduce it as a real or tangible objection. Our ships ought not to work or strain, and my own impression is that not any of these blocks would work loose. I think I have nearly exhausted the observations which it has been desirable to make, unless something should arise in the discussion, when I would ask permission to make further observations. In conclusion, I would say that Mr. Grantham's invention seems to me well deserving of a trial upon a large scale and in an effectual manner. Such a trial can, in fact, only be instituted by a Government department—such as the Admiralty.

The CHAIRMAN.—Will you allow me to offer your thanks to Mr. Mallet before we proceed. He is not an ordinary speaker on the subject. He has illustrated and explained it in a manner which only a man can do who is master of the subject; and I think he is entitled to our thanks for the information he has given us. We will now pass on to the discussion.

Captain HALSTED, R.N.—Last year I expressed my own conviction, which has never been altered since, that this is a mechanical arrangement which seems to be the most practically available that I have seen. All I would say upon it is this: I would advise Mr. Grantham not to give up one single hair's-breadth in the way of the reduction of the iron plate in order to accommodate the exterior lining, because I believe the advantage of such protection as would be given is a thousand times more than compensated by the advantages to be gained by loss of weight, that is to say, if it increased weight upon the structure of a ship would be 280 tons, by all means make the ship 280 tons larger to carry it. Nothing can exceed the misery of the circumstances in which we are now placed. We ought never to have arrived at it. There has never been a national effort made, nor any combined effort, to prevent an injury

which is absolutely destroying the application of the most effective material for the ships of the Navy. I regard it as a great disgrace to the whole country that such a state of things should exist, and I am perfectly persuaded that by this time we ought to have ascertained that the thing is remediable by chemical application, or to have ascertained under what conditions it can be placed to effect a reduction of the fouling. If that is impossible, then we have got other resources to fall back upon, that is to say, you can make a substitution of metal. Mr. Mallet has mentioned Muntz's metal. Muntz's metal has been shown to be perfectly equal in strength to iron, and the question is of that importance that I do not think the matter of expense ought to enter into the consideration. I do not think any expense can equal that of being obliged to forego the actual use of iron ships, for if a ship has to leave her station in order to be cleansed, she is unserviceable on her station for the time, and nobody knows what might happen when she is absent; therefore I do not think the question of expense ought to be entertained at all. Mr. Grantham here proposes a mechanical mode of rectifying our present position, and I have no hesitation in saying that, so far as an unproved thing can be judged of, because we have no experience in it, I think it is eminently deserving of application; and as we have at the present time a new kind of ship which is about to be commenced, and which is to be made the subject of experiments, I would advise Mr. Grantham to press very hard to have his application applied to the bottom of Captain Coles's cupola ship. I am strongly of opinion that Captain Coles would not make the slightest objection; on the contrary, if the method has the effect of maintaining the efficiency of his ship infinitely longer than otherwise she could be with a bare iron bottom, I believe Captain Coles would jump at it. Moreover there seems to be a desire on the part of the Admiralty to make that ship an experimental ship for more purposes than one. I see they are going to apply one or two different modes of fixing the armour-plates, and I should advise Mr. Grantham to make a set at that point. There is also this suggestion which I would make to him, which is, the use of Muntz's metal and not of copper. It is a mere routine we have got into with regard to the use of copper. The whole mercantile service of the country use Muntz's metal instead of copper. It is infinitely better, it is absolutely cheaper; the restoration or re-construction of it when it is worn is quite as easy as that of copper. Our establishment down at Chatham, where we make all the copper for our ships, is just as available for making Muntz's metal as it is for making copper. I had Muntz's metal in use on a ship which I commanded. At the time when screws were first introduced, before we adopted our present mode of lifting the screw, we used to withdraw it; the ends of the shafts were then left exposed, and the galvanic action was very powerful indeed. The series of experiments to which Mr. Mallet has referred were then made, for the purpose of ascertaining whether any other mixture would exhibit less powerful galvanic action than that which was done by the copper, and all the aft-part of our screw-ships, up to the year 1853, were sheathed with Muntz's metal. The ship I commanded was sheathed entirely with Muntz's metal. I preferred it, and the bottom of my ship was cleaner than those of the other frigates with which I was lying.

Dr. PERCY, F.R.S.—I have listened with great attention to Mr. Mallet, and have been struck with many remarks, and with none more so than those which related to the purity of certain qualities of iron. I think Mr. Mallet stated that certain descriptions of iron which were known to be most pure, resisted corrosion most effectively. If that be a fact, it is one of very great importance, because I believe that this particular kind of iron would be found to possess the very highest degree of tenacity, and to be, therefore, the best possible iron for use in structures of this kind. It appears to me that the subject is very far from being exhausted. Although many experiments have been made on the application of various kinds of cements, and although many patents have been taken out, and, as is customary, the same thing has been patented over and over again, still I cannot help thinking that an experiment of a very important character yet deserves to be made. I should like to have heard what Mr. Mallet's experience was as to the application of metallic coating. I think he condemned them all without any reservation. I do not know myself whether many experiments have been made. If they have not, it certainly seems desirable that something of the kind should be done—such as the application of arsenic. It is quite possible to apply arsenic in more ways than one to a surface of iron, and not only arsenic, but other metallic bodies. It may turn out that these applications are useless; but until we have the experiments, we are not in a position to speak with any degree of authority on the point. With refer-

ence to the remark which Captain Halsted made upon the substitution of Muntz's metal, I think that is a subject of very great importance. It is a subject about which I have recently placed my own views on public record; therefore I will not detain you with any remarks thereon.

The CHAIRMAN.—Perhaps you concur in Captain Halsted's views?

Dr. PERCY.—I am not prepared to say that. I think it is a subject worthy of more attention than it has yet received. Probably the Admiralty have some good reason for preferring copper. I believe in the case of Muntz's metal it is necessary that the vessel should be examined and repaired after a comparatively short time.

Captain HALSTED.—No, that is not so. It is almost universally adopted in the merchant service, and I have had it in my own ship.

Dr. PERCY.—How long without cleaning? That is the point.

Captain HALSTED.—We were more than two years before we were taken into dock.

Dr. PERCY.—Is not that a short time for vessels of war?

Captain HALSTED.—She was not taken in purposely for it; she came into dock accidentally, and, when she did come in, arrangements were made for an examination of the amount of fouling as compared with copper. The result of that examination is with the Admiralty.

Dr. PERCY.—The explanation of that is, that the zinc is perpetually dissolving away, so that the hold of these animals is prevented. In the course of time the whole of the zinc disappears; so you see, here corrosion plays a very important part.

Captain HALSTED.—It may depend upon the amount of metal; but in the case of my own ship I know that the report now exists, and I know how very little we had to do, because we had a clean bottom when the ship was taken into dock.

Dr. PERCY.—That leads me to another question about the effect of corrosion in the way of preventing the attachment of these shells, &c. One would think, *à priori*, that in proportion to the degree of corrosion would be the difficulty of attachment. I do not know whether I am right in my view. A certain amount of corrosion, I believe, would be desirable in cases of this kind, unless you have that degree of absolute smoothness to which Mr. Mallet has called attention.

GEO. TURNER, Esq., Master Shipwright, Woolwich Dockyard.—I do not think the copper sheathing is altogether free from fouling. I recollect a case in which we took off about ten tons of mussels from the bottom of a ship.

The CHAIRMAN.—It is a question of degree.

Mr. TURNER.—I have known copper on the old "Royal Sovereign" (it was pure copper then; we have lost the making of it) that had been on twenty-one years, and there was no diminution at all. How to account for it it was impossible to say, but such was the fact.

CHARLES ATHERTON, Esq., Chief Engineer and Inspector of Machinery, Woolwich Dockyard.—I will not attempt to detain the Meeting, but I would remind Captain Halsted of an experiment which was made at Woolwich fifteen years ago, when an iron boat was covered with an adhesive kind of kamptulicon about an inch thick, and on this a complete surface of copper was laid by adhesion, and it was very difficult to take it off. The experiment was not completed, but it shows that something of the same kind might be made applicable to sheathing the bottoms of ships. I believe that it is admitted that bitumen is the best material for adhering to iron. With regard to those experiments which Mr. Mallet has brought forward to-night, I would not think of turning such things into ridicule, but the experiments are so wonderful that it almost makes one suppose that a clever fellow can produce any results he pleases. There is one curious thing about the connection of brass and iron. I have been in the habit of breaking up boilers that have been tubed in brass—brass tubes in iron plates; I do not remember to have seen any of the plates the worse for the brass tubes fitted in them.

MR. MALLET.—Assuming the fact, a scientific explanation of it is not difficult nor inconsistent with anything I have stated. The iron pans in which salt is prepared in the Cheshire Salt Works, evaporate boiling brine, and yet are acted upon scarcely at all. Water holding a saturated solution of salt contains no air, and this is exactly in accordance with what I explained at the outset, that iron placed in water from which combined air has been exhausted, will not corrode. That is more or less the case in every marine boiler. But the more efficient cause which protects the brass tubes, and every part of the interior of a marine boiler is, that before the boiler has been in action six hours a stony deposit (insoluble salts of lime chiefly) takes place

on the surface, and this protects it from further corrosive action; there is no metallic surface exposed, there being a thin film of deposit between the water and the sides of the boiler. With reference to some remarks of Dr. Percy, I would mention first, with respect to Muntz's metal—and this was one of the things I had intended to allude to before—I see no reason why Muntz's metal should not be substituted for copper in Mr. Grantham's case. Muntz's metal was not the peculiar alloy of no action that I was talking of, which leaves the iron in its nearly neutral condition, but I think Muntz's metal would be an advantageous substitute for copper in this instance, and would produce less effect on the iron in any case than copper would. I would not recommend the fastenings here or anywhere else to be of Muntz's metal, for there can be no more deceptive or unsafe metal for bolts or other fastenings than it is. In the course of time it gets into a crystallized condition, and a bolt that will bear nineteen tons to the square inch when first rolled, may in the course of a few months, or even a few days, break as easily almost as a piece of crockery. Dr. Percy has asked me a question with reference to metallic coating. In speaking of metallic coating, I alluded only to galvanizing—coating with zinc, or with zinc and tin.

These have been tried, and found ineffective in sea water, for reasons which I have before alluded to; but I entirely agree with Dr. Percy, that the subject of modifying the substance or surface of the iron is not exhausted; that a great deal might yet be done in the way of carefully and really scientifically-conducted research, with such means given to assist experiment as the public departments can alone supply, and not by the voluntary labour and research of private individuals, as was my case. My experiments were made purely for the sake of knowledge, and at the expense of the British Association, which spent £300 or £400 upon these experiments; but such experiments, to be conducted right, would need larger amounts, and the appliances which the public dockyards could afford to be placed in the hands of scientific men. Another direction of inquiry is open, which Dr. Percy, talking of this and analogous subjects a few days ago, stated to me. He, I believe, holds the view that a large field of inquiry exists as to how far certain minute alloys of other metals mixed with iron for ship plates might be attended with an available diminution of corrosion and also of fouling. It is a fact, as I have mentioned, that the purest iron corrodes by much the slowest, and that such iron therefore makes the best as well as the strongest ships. The quality of iron that is commonly used for iron ships, called boat-plate iron, is not only the worst mechanically, but the worst chemically. But it remains still for the chemist, the metallurgist, and the engineer together, to discover whether it may not be possible to make some compound of iron of this best quality, with another metal in small proportion, that as respects the ends in view shall be best of all.

The CHAIRMAN.—It is really a very important subject, and we were turning over in our minds whether we could not find a day to carry on the discussion. We are very much indebted to Mr. Mallet and Dr. Percy for the very pertinent facts they have brought forward to-night. When we were discussing the subject of iron ships, a number of facts, which then appeared to be opposing facts, are now explained by the different qualities of the iron, and the different degrees of susceptibility to corrode. If an inferior iron is used, a ship of that description is worth next to nothing; and a ship of the very best description of iron is worth a great deal, and would perhaps be the best description of ship, if only the effect of fouling was disposed of. Since the remark with respect to the loss of a knot per hour in the speed of the Irish boats, I have made a calculation as to the cost. It would be equal to about one-sixth of the whole quantity of coals they burn; and, taking the reduction of speed from fouling the bottom of the "Warrior," as estimated by Mr. Grantham—not at the figures he puts it, seven to twelve—but taking a reduction of speed equal to one-third, it would make a difference of about 50 tons of coal a-day in that ship. Abroad coals are not to be obtained under £2 per ton, sometimes at not less than £4 per ton; but take it at £2 per ton, and there is £100 per day lost by the diminished speed of the vessel through fouling. Now Mr. Grantham's estimate for his sheathing is only £4,000; we see from the above how soon that would be realised in the saving of coal. But, as Captain Halsted justly observed, that is no measure of the ship's performance, because if she has to go 1,000 miles to be docked the whole use of the ship is lost during the period she is away. If she is the type of a fleet, and all the vessels are liable to become thus defective, the whole fleet may require to go away or become weakened, so that the mischief they were intended to prevent may be effected in its absence. It strikes me that this method of Mr. Grantham's is really a complete one. I do not

think it is of that character which requires to be what they call "tested." I am perfectly satisfied with the explanation which Mr. Mallet has given, that there is no danger, no material danger, if only the right description of wood is used, and ordinary care is taken in putting the sheathing on,—I agree with him that no water, in any great quantity materially to injure the construction, can get in; therefore it is really perfect of its kind. It would be paid for in a short time, and the efficiency of the vessel would be preserved. Twenty-five years ago I was on the coast of Africa when an iron whaler came out. She had only been six months out from England. She had been cleaned, as well as they could clean a vessel at sea, every month, with long brooms and ropes, under her bottom; but she had long grass and barnacles of immense size attached to her, in consequence of which she was not safe. She would neither sail nor steer, added to which she was not manageable. Her crew had this enormous work entailed upon them besides their ordinary work. I made a report to the Admiralty on the subject, and, with such before them, it was not to be wondered at that they did not undertake to embark in iron ships: they may be very effective, the iron may be very good, but if they foul in this way they will be useless. It appears to me that this system does get rid of that difficulty. I do not think the seams would open in any injurious degree, for a three-decked ship of the old style only broke her sheer fifteen inches in launching. After the new system was introduced by Sir Robert Seppings, similar ships only broke three inches in coming off the stocks. When you come to divide the largest quantity over the number of these small sections or plates, you will see that it can have no appreciable effect on the joints; and when you consider that the seams of wooden ships are so open that in caulking them you sometimes drive in oakum equal to inch rope, the thickness of the twentieth part of a sheet of paper is really no opening whatever. With the best ship, when first launched, the seams are of immense size as compared with the opening which is supposed possible to arise from the bending of the ship.

We have to return our best thanks to Mr. Grantham for his interesting paper.

Evening Meeting.

Monday, March 31st, 1862.

CAPTAIN E. G. FISHBOURNE, R.N., C.B., in the Chair.

ON CONSTRUCTING, MANŒUVRING, AND PROPELLING SCREW STEAMERS FOR WAR AND OTHER PURPOSES, AND THE APPLICATION OF A SCREW PROPELLER CALCULATED TO PREVENT FOULING.

By Commander T. E. SYMONDS, R.N.

As it is well known and admitted that there are many imperfections in the present method of fitting the screw and in manœuvring and steering screw steamers, more especially those for war purposes, it is surprising that these subjects have not received more notice. It is true that a casual remark has been made as to the necessity for "protecting the screw," and improving the steering qualities; but, as a rule, discussion has been almost exclusively confined to the respective merits of "armour plates" and "guns," as though they were the only two things needful.

All seamen will admit that the objects I have named are not second in importance even to those two great questions; for of what comparative use is a ram or an armour-clad ship without the power of manœuvring rapidly, either to give a blow effectively or avoid that of an antagonist; and can anything more pitiable be imagined than one of those leviathans shorn of its motive power, a helpless log on the ocean, at the mercy of smaller vessels, her screw or rudder disabled, perhaps, by the first broadside of an opponent half her size; or by the wreck of some mast she may have shot away in chase, for, be it remembered, a screw is as likely, or, perhaps, more likely, to be fouled by other ships' rigging and wreck than her own, and, if we are to judge from past accounts and delineations of naval actions, there must be plenty of it floating about at such times.

Although we have the highest authority for it, and common-sense dictates the necessity for rapidity and precision in manœuvring, what advance have we made in that direction to meet the requirements

of the increased proportions of our ships? We find the reply in the published statements of their steering qualities. Reflect for an instant on the time and space it would occupy to turn such a ship as the "Warrior," as now equipped, when at slow speed, and what incalculable damage might be done to her by one or more smaller shot-proof ships capable of turning twice to her once, which, having this advantage in turning, might always avoid her blow. An eminent engineer, on a very recent occasion, remarked that "it was one thing firing at a target and another at a ship constantly moving, and therefore as often offering an inclined plane to the shot as a vertical one. Ships," he said, "would not always accommodate you by placing themselves at right angles." Nothing can be more to the point; and, I add, no man would so "accommodate" his opponent if his ship were under perfect control, but would take that advantage superior manœuvring power gave him, and place her at an inclined angle with his antagonist, either to receive his fire or avoid the blow.

Now, although I admit that some of our screw steamers do manœuvre very fairly under favourable circumstances, there is not one of great length that could be moved with certainty, or anything approaching it, especially at slow speed—and it is at slow speed, I apprehend, that an action would be fought, at least a general one. It is one thing to describe a circle in a fair way and another to turn a ship short round in action. I contend that a perfect fighting ship, no matter whether armour-clad or otherwise, should have the power of turning in her own length, or nearly so, and that the steering power should be as perfect going astern as going ahead; that the propelling power, be it what it may, should be out of danger from shot or ram; and that she should be of such a draught of water as to enable her to go into any of our own harbours or docks without delay, or to stand fearlessly into an enemy's port, and occupy a position that will enable her to use her guns effectively, some means being adopted whereby the rolling is reduced materially, a rifled or any other gun being comparatively of little use unless you have a steady battery to fire it from. The disadvantage of heavy draught of water was constantly felt by our inshore squadrons during the old war, and has been more recently made manifest during the operations in China. With such examples before us need we hesitate to reduce it?

I am strongly of opinion that in ships, as in other machines, special tools are required for special work, if it is to be done perfectly. We must, therefore, make up our minds to throw overboard old notions, and adopt such as will meet altered circumstances, and not attempt to cram into a ship intended for operations in shore the same amount of stores and gear we should put into one intended for cruizing purposes, or to expect to obtain any great results under canvas from ships required to steam at high velocity. It is very clear that some point must be conceded to obtain a special result, and I take it most are now of opinion that any attempt to effect a combination of qualities in ships of the present type will be futile. I believe that masts and sails are necessary to all classes, but only as an auxiliary in case of a breakdown, and to ease the "rolling motion;" they may be adopted without hesitation when the fouling of the screw is obviated, as I am confident it is in the form of propeller described in this

paper. That keeping masts aloft eases the rolling motion is well known to practical men and those who have seen a dismasted ship in a sea way. It is obvious that no vessel without masts can roll as easily as with them, on the principle of the metronome, especially if they have fore and aft sails set with their sheets hauled flat aft, which will reduce the motion even in a calm, and is an expedient often resorted to. I therefore much doubt if ships without masts, as is contemplated, will be as efficient for general purposes as is expected, and their absence will be found very inconvenient in hoisting in and out heavy weights, fishing the anchor, &c.

Cellular Girder System.—At this point I consider it right to observe that Mr. Roberts was, so far as I can ascertain, the first to recognise the necessity for giving greater longitudinal strength to iron ships, and to promulgate this doctrine in his patent of 1852 (and on many public occasions), in which he compares a ship to a "beam," and that as a beam (which increases in strength as the square of its depth, or nearly so) it was desirable to increase the sectional area of the iron in the upper part of the hull, and thus secure the utmost strength due to the whole depth of the ship's side from gunwale to bilge.

This conclusion was arrived at on noticing the weakness exhibited by iron ships of great length building at that period, the iron sides of which terminated at the deck, the top side being composed of wood of very light scantling, thus losing several feet of depth, and consequently a large proportion of strength on the upper side of the ship or beam.

Recognising the applicability of the cellular girder system to these iron ships, he next sought a mode of arranging it, by which the greatest strength could be obtained where it was most required, viz., at the top and bottom, without a corresponding increase of weight or interfering with existing arrangements.

Novel Mode of applying Girders.—Instead, therefore, of introducing girders under the deck, and consequently some six feet from the top of the ship or beam, as has been subsequently recommended by other authorities, he proposed to make his girders subservient to the requirements of his ship, forming them out of the cabins, saloons, coal-bunkers, and keels, as shown in the drawing of the mid section, sheets 1, 2, and 3; he likewise proposed to make the decks of iron. Thus, as in the lithograph of a large passenger or troop ship (Plate I.), the cabins, or horse-stalls, on either side form a continuous cellular girder fore and aft the ship, the vertical parts being formed of the side of the ship and the face of the cabins, the top and bottom being composed of the iron main deck and a strong covering plate which runs fore and aft, and is connected with the upper deck or platform, the cells being formed by the divisions or bulk-heads of the cabins or stalls. By this arrangement it will be seen that there would be a very great increase of longitudinal strength in the right place beyond that of a girder under the deck. Had the "Victoria" troop-ship been fitted with these girders, her bulwarks might not have been stove in on her late disastrous voyage.

Midship Girder formed of the Saloons, Cabins, &c.—Instead of making the "deck saloons" of wood or of iron in broken lengths, he proposes to make them of iron, forming a continuous girder, B, nearly from stem to stern, connected with the poop and forecastle deck; this would in itself be

sufficient for all practical purposes; the sides of the saloon could be made as those of the cabins, or of a "lattice girder," with advantage, and thus admit of doors, windows, &c., being introduced without weakening the structure. This latter plan has been adopted (the lattice-bar excepted) in many light-draught steamers, but has not hitherto been applied to large steamships, although there are many instances on record, and some of no ancient date, where their presence would have been very serviceable. Plate I., No. 1, shows the arrangement of cabins in the after part of the ship, and horse-stalls in the fore. No. 2 is the deck plan, showing fore part of midship girder, used as horse-stalls, with passage between the stalls; the after part fitted as saloons.

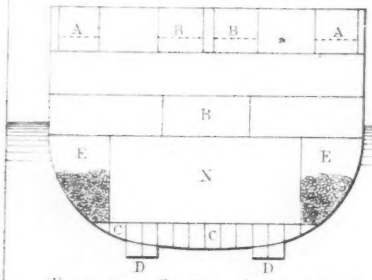
Keels and Bottom.—Having thus disposed of the upper side of the ship (or beam), it became necessary to consider how the lower side could be formed so as to resist an amount of compression more than equivalent to the tensile strength of the upper (as wrought iron does not resist compression as well as it does tension). For this purpose, in addition to the cellular bottom, C, continued the whole length of the ship (and not merely in parts, as previous to his invention was done in some instances), Mr. Roberts applies two cellular keels, D D, of any required depth, one under each bilge, extending nearly the whole length of the floor; these keels, as represented in the lithograph, are "cellular girders," which will not only give the required strength, but effectually defend the bottom plates on taking the ground, especially if fitted with timber false keels. If considered necessary, the bottom between these keels and on either side the bilge might be lined with planking, and thus overcome the objection some entertain to iron bottoms in the event of a ship striking on rocky ground.

Keels reduce Rolling, increase Strength, and do not interfere with Steerage.—These keels will materially reduce rolling, and give general stability and strength to the whole fabric, especially in a longitudinal direction, making it more capable of resisting the shock produced by the ram manœuvre. They are, in fact, two huge back-bones to secure the ribs to, instead of one solid keel of plated iron, which, as is well known, is in every way weaker than one of a cellular form. Being parallel to the plane of the ship, they do not interfere with either steerage or speed, as has been proved in Mr. Tovell's ship, than which a better sea-boat or an easier roller does not, I believe, exist. These cellular keels, in connection with the cellular bottom, may be adapted either for surface or internal condensation, as suggested in Mr. Roberts's specification. It will be seen, by referring to the drawing of the mid section, Plate I., that the ship is divided longitudinally into three parts by iron bulkheads, which extend nearly the whole length, connecting the upper deck with the bottom, the longitudinal compartment thus formed being sub-divided by the athwartship water-tight bulkheads, and by the divisions of the cabins, coal bunkers, and stalls before described.

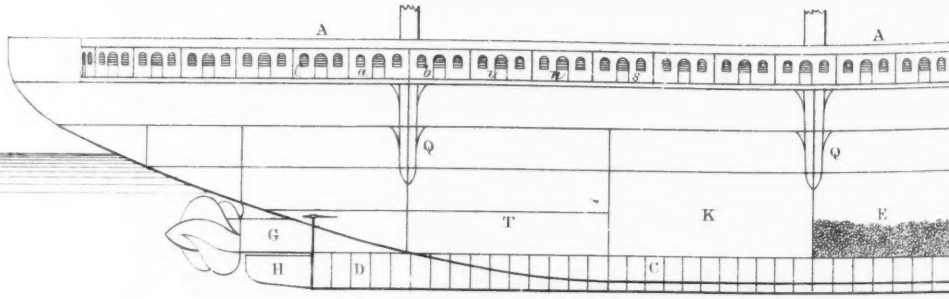
I imagine that any seaman will at once perceive with what facility a ship fitted with such keels may be grounded on a favourable place, and her bottom repaired or cleaned (should no docks exist), the keels being in fact a gridiron, which may be made even more complete by slinging logs of timber under them. As the ship will remain in an upright posi-

PASSENGER OR TR

Fig. 3

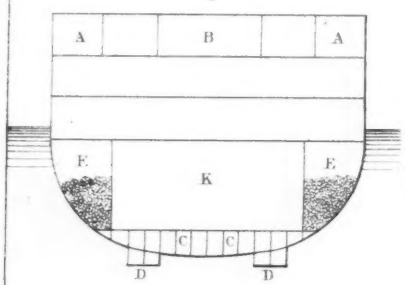


Transverse Section showing Stalls.

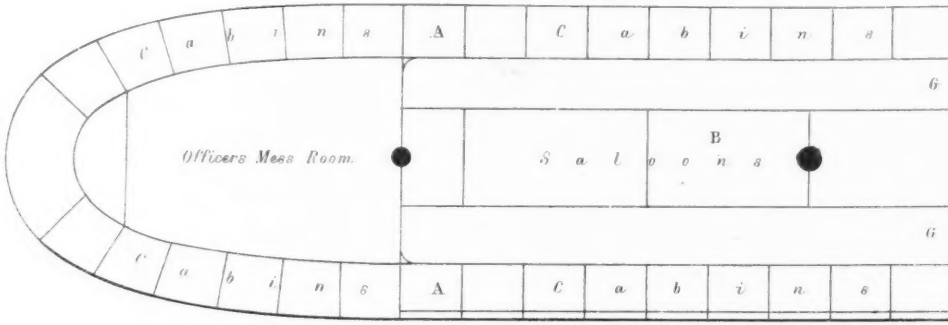


Longitudinal Section showing Arrang

Fig. 4.

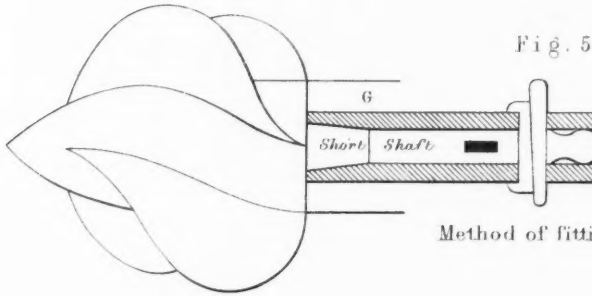


Transverse Section showing Cabins.



Deck Plan with

Fig. 5

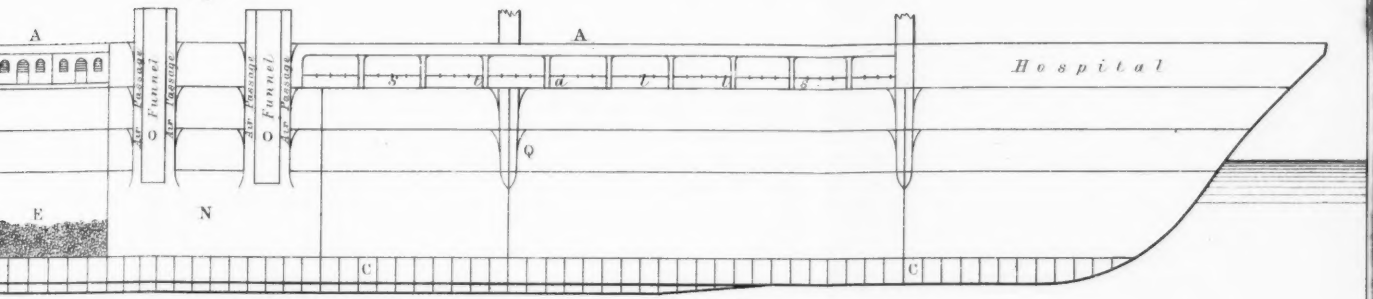


Method of fitti

Designed by Rd. Roberts C.E. and Commander T.E. Symonds R.N.

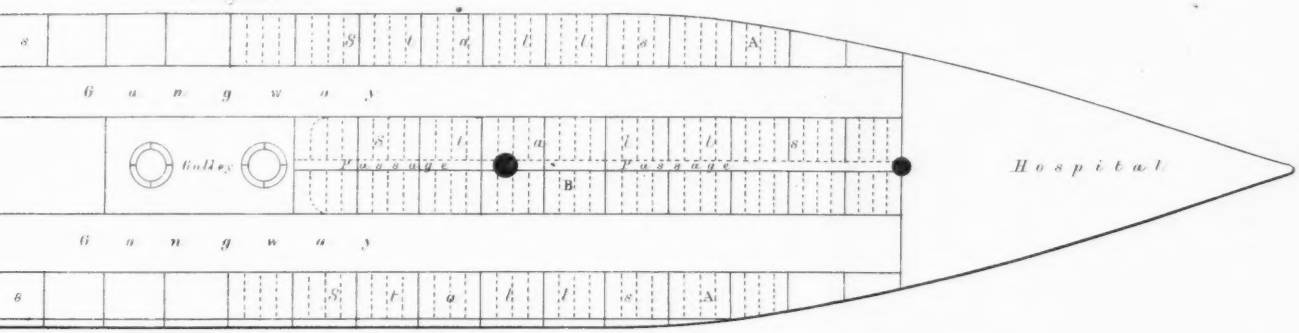
OR TRANSPORT SHIP.

Fig. 1.



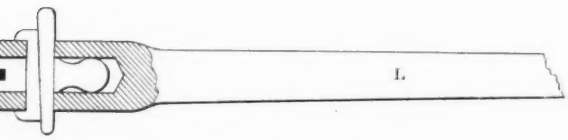
ng Arrangement of Cellular Girders formed by Cabins Stalls Keels &c.

Fig. 2.



Plan with Arrangement of Cabins Stalls & Saloons.

Fig. 5.

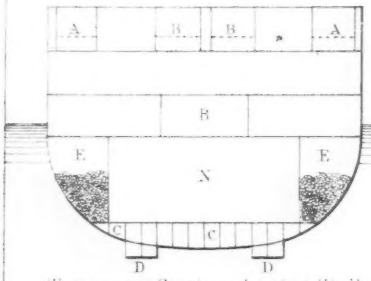


Scale 1/32 of an Inch to a Foot.

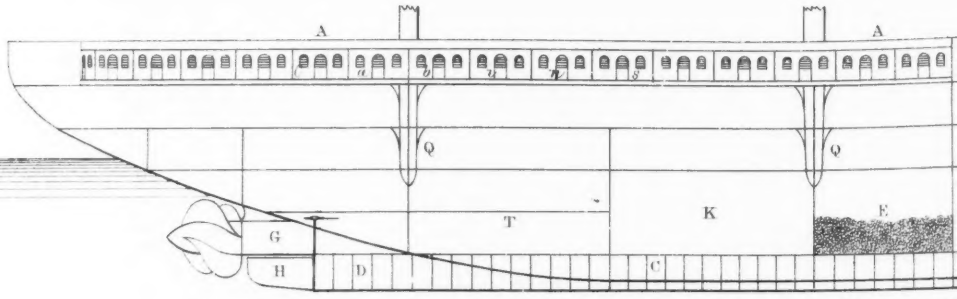
od of fitting Screw Propeller to Shaft.

PASSENGER OR TR

Fig. 3

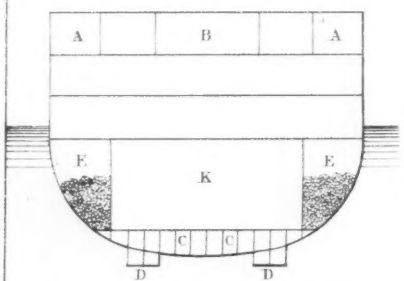


Transverse Section showing Stalls.

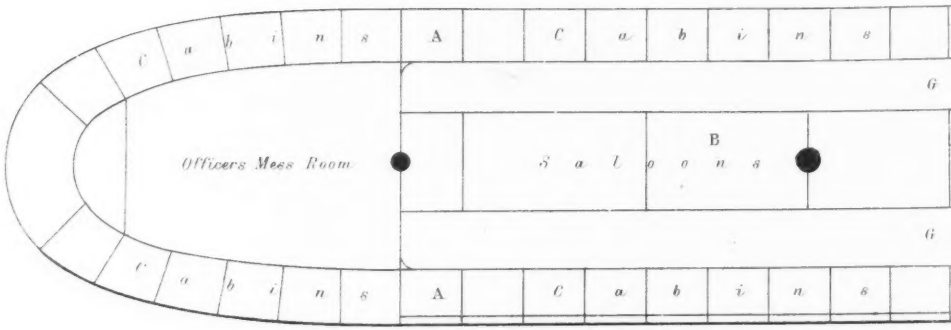


Longitudinal Section showing Arrang

Fig. 4.

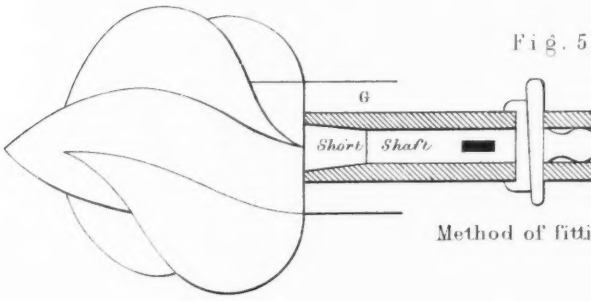


Transverse Section showing Cabins.



Deck Plan with

Fig. 5

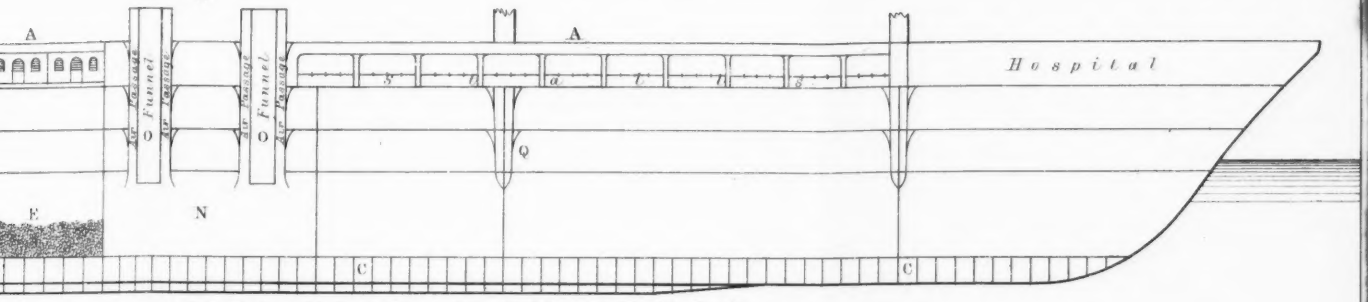


Method of fitti

Designed by Rd. Roberts C.E. and Commander T.E. Symonds R.N.

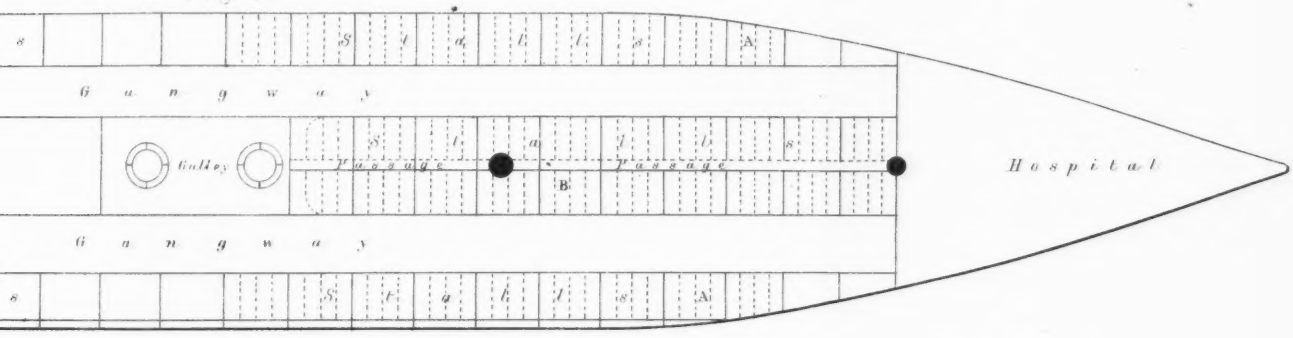
R TRANSPORT SHIP.

Fig. 1.



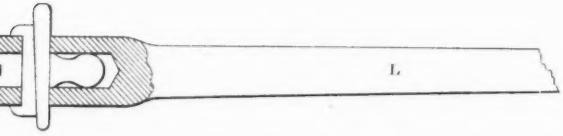
ng Arrangement of Cellular Girders formed by Cabins Stalls Keels &c.

Fig. 2.



lan with Arrangement of Cabins Stalls & Saloons.

Fig. 5.



od of fitting Screw Propeller to Shaft.

Scale 1/32 of an Inch to a Foot.

tion on these broad surfaces, no shores will be required, which, as in the case of the "Great Eastern," might penetrate the bottom; a few spars over the side being sufficient to steady her. The risk of docking heavy ships would also be greatly reduced, the weight being distributed over a large area under each bilge, and the operation materially expedited. In engaging forts, what an advantage it would be to have a ship thus capable of grounding without danger, and fighting her guns with nearly the same facility as though afloat. It would certainly give confidence in approaching fortifications, or covering the landing of troops, and enable them to engage so as to do their work effectually at close quarters, instead of playing at long balls. Merchant vessels in taking the ground would be free from the risk of falling over, and thereby damaging their cargoes.

Weatherly Qualities.—I contend that a light-draught ship fitted with these keels would, from the resistance they offer, have as good or better weatherly qualities than one of deeper draught without them. They are, in fact, to a ship what the two large logs are in the Pernambuco catamaran (a drawing of which is shown in Plate II.), than which there is no more weatherly craft afloat: these catamarans never roll. It is curious and instructive to remark how nearly the intuitive genius of the savage thus approaches, or, perhaps, more properly speaking, has anticipated, the deductions of science.

Light-draught gunboats and mortar vessels might readily be sent over sea without risk, deep temporary keels being added to those already in existence, which might be removed at pleasure.

Although I believe no one can for a moment suppose that any structure would have entirely withstood the tremendous sea which broke upon the "Royal Charter," I question whether such a method of strengthening as I have described would not have held her together long enough to have afforded some chance of escape for many who found a watery grave on that fearful night. At all events, it is worth consideration; for how many tens of thousands are there who have to incur similar risks in the future?

Cellular Girders, as applied to Ships of War.—As the proposed arrangement of girders and bulkheads could not always conveniently be carried out in a ship of war, as has been described for a merchant vessel, it is proposed to fit them as shown at A, Plate II., carrying them up to the upper part of the gunwale—say six feet—or, if preferred, making a shallower girder, as denoted in the drawing, using the space above for hammock nettings, with a gangway round the ship. The cells may be used for stowing light sails and other gear required to be kept on deck.

Increased Strength on Upper Deck.—That some additional strength on the upper part of our iron ships is required, is, I believe, admitted by many, and was strongly advocated at the Institution of Civil Engineers the other day; if not apparent now in our war ships, it is likely to make itself visible if they are subjected to any severe strains either by grounding, being in heavy weather, or used as rams.

Form.—To obtain the greatest amount of capacity consistent with strength and required speed, I advocate a mid section of elliptical form, which is maintained throughout full one half of the length of a uniform depth (being on an even keel); the bow lines being composed of easy curves on a principle by which the best form for entering the water I

have yet seen is obtained; these lines are of such a character as to avoid any considerable bending in laying on the plates, which is a process attended with great trouble and expense.

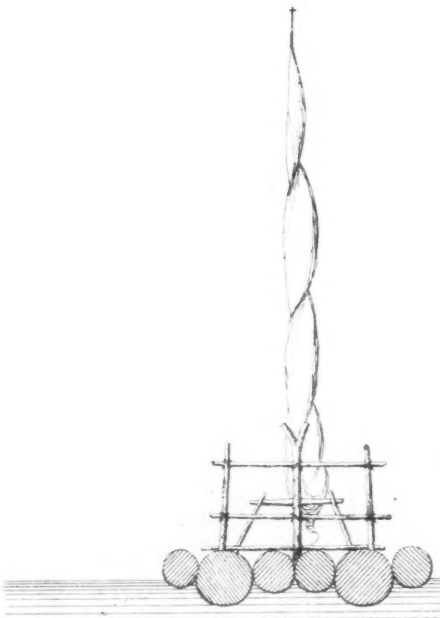
This flat elliptical floor is continued to the fore foot; thus the fore-section is made self-supporting (the heavy part of the sharp floor, as in other ships, being dispensed with); it is consequently more buoyant and, combined with the long floor, will reduce the tendency to pitch, and will "lift" in going against a head sea. The after section is composed of convex curves sufficiently fine to deliver the water freely, but not so lean as to diminish the necessary support in that quarter, the absence of which induces a sending to one side or dropping quarterwise, which my observation teaches me is one of the causes of rolling in ships of the present build, which, having the screw in the centre, require, it is supposed, a finer and longer run for the water to close upon it. A lean after section also produces deeper immersion aft when at high speed (or squatting as it is sometimes called), which retards considerably. This form, combined with the cellular keels before referred to, I consider best calculated to produce a steadier platform than has been obtained hitherto, and by a proper adjustment of weights will reduce rolling to a minimum; without it guns of precision are of little avail, and you may as well attempt to fire a rifle at long range from a swing as a rifled cannon from a ship rolling through an arc of 30°.

Increased Bulk and Draught not resulting in Increased Steadiness.—It has been well proved that increased bulk and draught has not decreased rolling as was anticipated, nor have the "bilge pieces" had much effect (except to interfere with the steerage); is it not, therefore, time to try some other means of accomplishing it? It has been said that the "Warrior" is to have a keel similar to other ships to reduce her rolling. If such be the case, and it really affects her, how much more would two? Again, in rolling thus, a ship exposes her bottom to shot, and four feet of armour-plating below the water-line will be of little use.

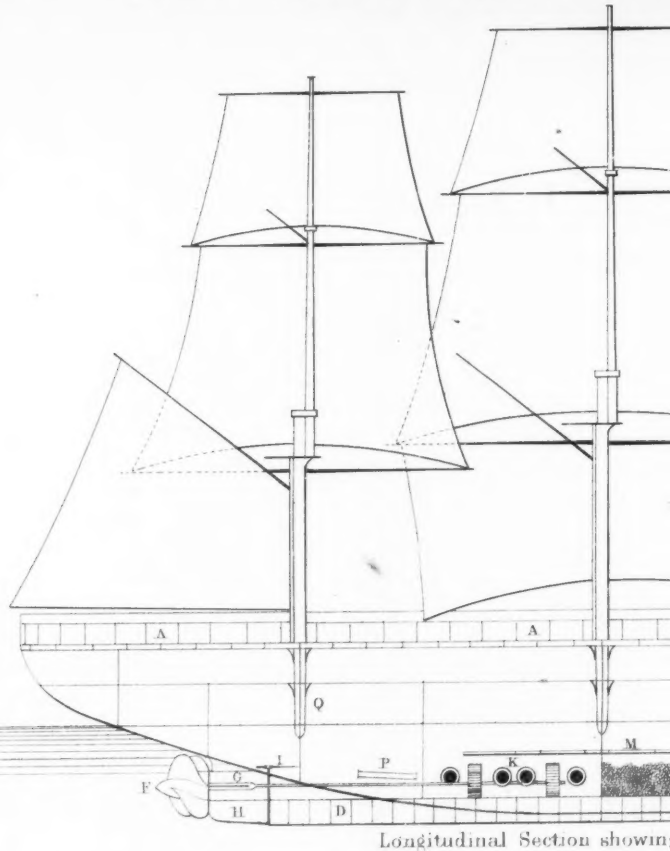
Elliptical Mid Section.—It may appear at first sight that the section we propose is favourable to rolling; but it is the reverse when ballasted, and provided with two keels, as has been proved in Mr. Tovell's circular section, and may be seen any day by experiment with a barrel or cylinder, which rolls more than any other form when empty, but when ballasted and fitted with a keel, less, and is, moreover, easier in its motion from the fact of the same section being always immersed. It is for experiment to prove which is the best for speed, the circle or ellipse; we prefer the latter, and especially as it enables us to keep our engines lower.

Light-draught Long-floored Vessels advocated.—My experience among the beautiful slavers on the coast of Africa and the best models in our yachts, more particularly those of Mr. Weld, convinces me that a light-draught long-floored vessel is, beyond all doubt, the fastest before the wind. So far was that opinion received among the owners of slavers in the year 1850, that vessels were constructed purposely, with orders never to haul on a wind if chased. As in sailing vessels with the sails acting in a line with the keel, so is it, I believe, in screw steamers; and for this, added to other palpable reasons, do I advocate as light a draught as possible in all war steamships, believing that it will be found in practice,

LIGHT DRAUGHT WAR STEAM

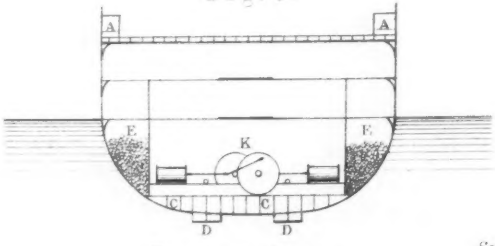


Section of a Pernambuco Catamaran.

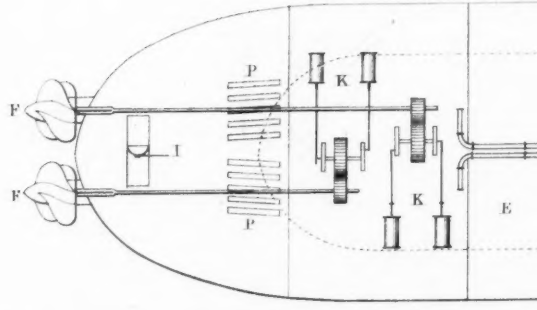


Longitudinal Section showin

Fig. 3.



Transverse Section

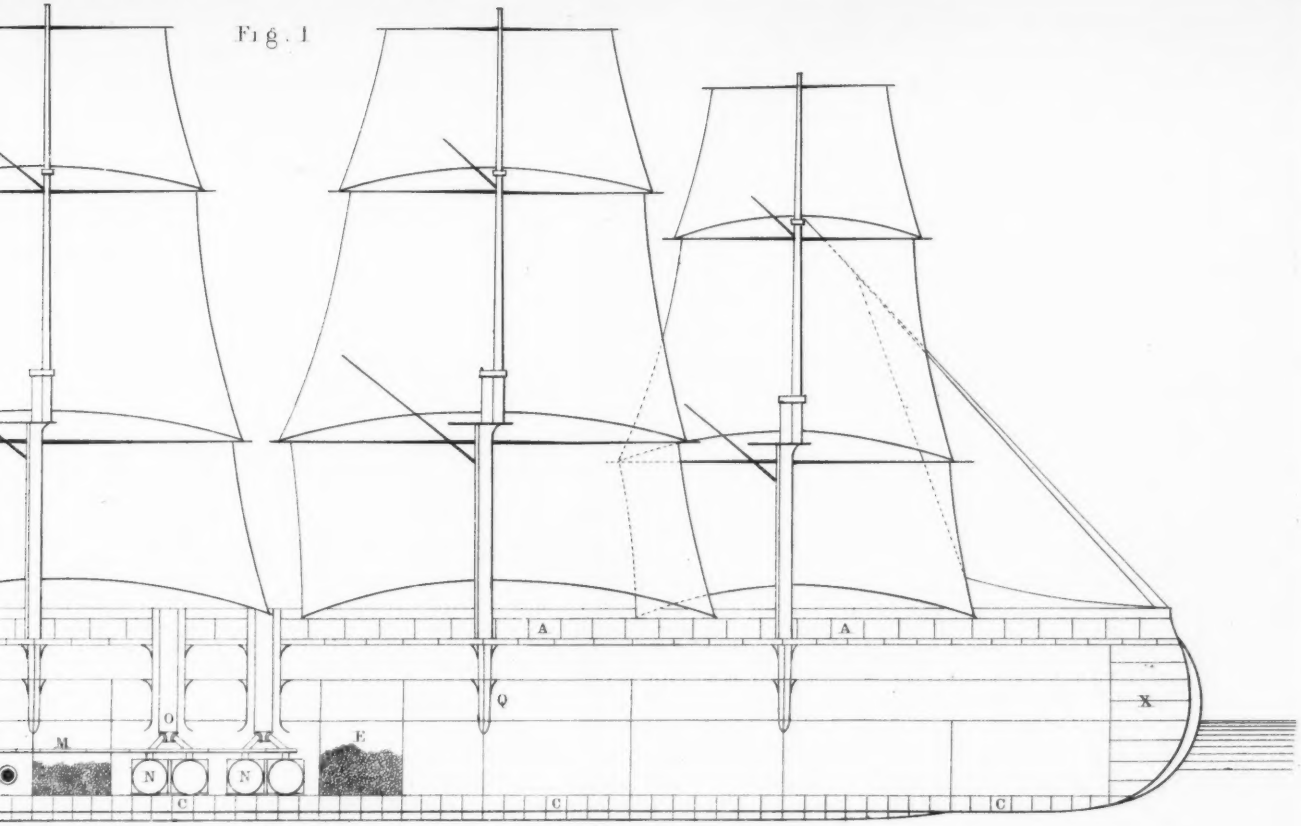


Scale 1/32 of an Inch to a Foot.

Designed by Rd. Roberts C.E. and Commander T.E. Symonds R.N.

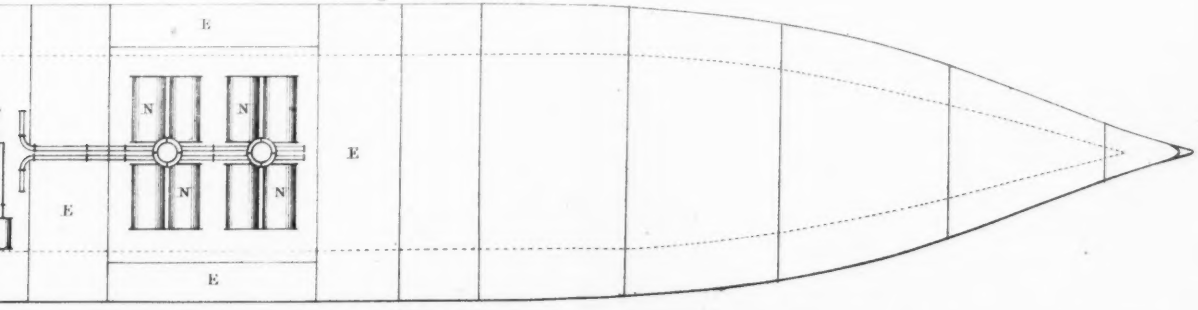
TEAM SHIP OF 30 GUNS.

Fig. 1



ou showing top & bottom Girders, Internal Arrangements & Plan of Masts & Sails.

Fig. 2.



Floor Plan.

J.R Jobbins

that, so long as the form is good, an increased width at the water-line with decreased depth (provided the immersed area of mid section is the same) will be more readily propelled than the same area at a deeper draught with less beam. It is clear that the light-draught body is displacing water of less density, and will not throw up that tremendous wave which is observable in most deep ships at high speeds. Light-draught ships are proverbially good sea boats; the old Danish vessels, for instance, our fathers remember, and often quote as being handy and weatherly.

Operations in-shore.—A light-draught ship, whether for war or mercantile purposes, must possess decided advantages over those of heavy draught on numerous occasions, and especially when intended to operate in-shore, when they may there evade them by crossing shoals or bars, and take shelter under batteries (or attack them). Merchant vessels, also, trading to the northern and other ports, having tidal or bar harbours and rivers to contend with, are liable to detention and loss by waiting for water,—Amsterdam and Rotterdam traders, for example. A light-draught ship on an even keel, fitted as described, would possess immense advantage over a long-heeled vessel taking the Brill Bar, where ships often thump for hours and damage themselves aft, as the shock would be distributed over the entire length of the two cellular keels, the draught being the same fore and aft.

Light Draught as Applicable to present Harbour and Dock Accommodation.—A reduction of even two or three feet would obviate much of the delay now often incurred in going into Portsmouth, and other harbours, and reduce the risk. It would also make present dock and harbour accommodation available without incurring the enormous expense consequent on alterations, which, it appears, are necessary ere the present class of large war steamers can be accommodated readily. At all events, a reduction in draught would set at rest the many questions that have arisen as to the ultimate value, or otherwise, of Portsmouth as a port for such a class of ships, and prevent the necessity of dredging a hole for a a deep-draught ship to lay in, as in the case of the "Resistance" at Chatham. The ship shown in Plate II. is of 5,000 tons, having a draught forward and aft of 20ft. 6in., being 6ft. 6in. less than the "Warrior."

Present System of Propulsion Impossible in Light Draught if Speed is required.—It is, however, obvious that the draught cannot be considerably reduced under the present system of propulsion with one screw, so long as great speed is required, for to retain great speed it is necessary to have a screw of great diameter, which entails great draught; and I much question, even with the present draught, if the screw is sufficiently immersed in many ships to produce the best results. In some, having a smaller screw well immersed, a greater portion of duty has been observed. However, be this as it may, if one screw cannot do the work at a reduced draught of water, why not use two? I believe the principal objections to two screws are, that the chances of fouling are multiplied; *that the present form of after-section, with the dead wood intervening, would not admit of sufficient diameter, and offers a great obstruction to propulsion and steerage; and that the speed at which it would be necessary to drive screws of finer pitch would be too high.* Good results have, nevertheless, been obtained, and especially in one case I am acquainted with. The

vessel in question is about 90ft. long, 12ft. wide, 3ft. 3in. draught; having two screws (3-bladed), 3ft. diameter, driven by two single-cylinder engines of 15 horse-power. She often attained a speed of eleven and twelve knots, and proved herself a capital tug, performing in a manner that quite baffles any calculation that is usually applied to ascertain the power of a single screw steamer. This vessel was steered by her screws alone, either going ahead or astern, in the most perfect manner, turning easily and quickly in her own length. Steamers with two screws are largely and successfully employed as tugs in America, and some of the best French gunboats are also fitted with them. Why should they not be here? I am aware that bad results have been obtained in several vessels fitted with two screws, but failure is as often caused by a wrong application of a principle as by any defect in it. In the form and arrangement I advocate, the obstructions due to the present form of vessel being entirely removed, the conditions are altered.

Reasons for advocating Two Screws.—Encouraged by results that have already been attained by steamers with two screws, I have less hesitation in advocating the use of them on this occasion, especially as by the peculiar method we propose to apply them, most of the objections referred to are obviated, the screws we submit being of a form that will entirely prevent fouling; the obstruction of the "dead wood," after stern-post, and rudder being removed, we are at liberty to increase the diameter, and still have free space for them to work in, the water having undisturbed access from every direction. *The rudders are so placed as to improve the steering power without interfering with the screws, rudders and screws being constantly submerged at such a depth as to defend them from shot, prevent their being lifted out of water, or injured by the ram manœuvre.*

Inconvenience attending Present Method of fitting Propeller considered.—Previous to describing this arrangement, I will consider the inconvenience arising from the present method of fitting the propeller, which is well known to be constantly liable to foul, and, therefore, specially inapplicable to war purposes, in which delay is defeat.

The numerous plans that have been suggested as a remedy prove the importance of this question. "Guard bars," "knives on the boss," and a variety of other expedients equally inefficient (which only aggravate the evil), have been laid aside, and still accidents, of a more or less fatal character, are constantly occurring. It was only the other day that one man's life was sacrificed, and that of many others in jeopardy, by the hawser attached to the "Great Eastern" fouling the screw, and in an instant capsizing and smashing a large man-of-war's boat, and precipitating her crew into a tide-race, at Milford Haven.

The frequent accidents and detentions from the same cause are now patent to all; I shall, therefore, not recapitulate them, but proceed to other objections of an equally important character.

Other Objections.—The screw is in most instances so near the surface that it must catch every floating object within its influence; and being lifted out of the water by the slightest pitching motion, and often bared by the undulation of the wave, it loses a large proportion of its effect; and if not fitted with a good governor, the engines are liable to be strained by "racing" (which may be attended with serious results in such engines as

are now fitted to our large class steamers), and often causes a fracture of the blade on re-entering the water after acquiring a high velocity. Being thus near the surface, the screw is likewise liable to injury from shot, and I take it that it would be the target for the first broadside, for, once crippled in that quarter, the ship would be at the mercy of her opponent. Again, being within a few inches of the bottom, it is liable to be broken by striking a rock or any hard substance, as in the case of the "Defence," at Spithead, the other day, on her trial trip.

It is fair to suppose that in going up rivers or entering the narrow seas or channels of an enemy, every means will be resorted to that ingenuity can suggest to cripple an opponent. Among others I know of no more certain means of fouling a screw of any size than mooring trains of nets, with their 4-inch warp attached to them, some feet below the surface, at various distances. They would as certainly protect the approach to a harbour from a screw steamer as anything that could be devised. Some of the skippers of our screw steamers trading coastwise are, I suspect, well aware of this fact.

Screw and Rudder depending on the After Stern-post; their Liability to Damage.—Apart from this tendency to foul, both screw and rudder are entirely dependent on the after stern-post, which is liable to be bent or broken by a sea striking the exposed part of the rudder, the rudder-head being also liable to damage from the same cause, as in the "Great Eastern." This may arise from a defective weld or wrong proportion on that long unsupported bar of iron which is so costly and difficult to forge, and, with its appurtenances, adds materially to the weight at the extremity, where all should be as light as possible. It is also liable to be bent by a blow from heavy shot or ram, or by striking the ground aft, which is by no means an improbability in a long-heeled ship drawing 27 feet or 28 feet of water. In either case the rudder and screw-lifting frame might be jammed, the screw-shaft thrown out of centre, and the ship crippled either for sailing or steaming. The after stern-post displaces a large column of water, and together with the vacuum caused by the stern-post passing through the water, offers a considerable obstruction to speed, while the opening for the screw allows the water which would otherwise impinge on the rudder to pass through and diminish the steering power. This is sometimes felt to a considerable extent when under canvas. The after bearing of the screw being open at the upper side, is liable to catch anything falling upon it, and thus jam the shaft, as occurred not long since to one of our war steamers.

Remedy.—The method we propose for remedying these evils is first by using a propeller, F, which by its form alone is calculated to reject or throw off all impediments, and if striking a hard surface will not receive any serious injury. This propeller may be readily applied to ships of the present type, with or without an after bearing; we prefer the latter. In this case the chances of fouling would be materially reduced, but cannot be prevented to the same extent as in a ship constructed or altered to suit it.

Description of Propeller.—The vanes or blades are of wrought iron or steel secured to spiral flanges on the boss, the flanges being covered by a cycloidal casing of wrought iron; the root of the blades being long, and

therefore well supported, admits of their being made thinner than those of the ordinary shape in cast metal; being thinner, they displace less water, and consequently absorb less power in turning; being of wrought iron, they are far less liable to injury, and can be readily replaced or repaired when damaged. They may be estimated at about half the weight, and one-third or one-fourth the cost, of those made on gun-metal of the same diameter.

Cast-iron or cast-metal blades of this form would be far less liable to injury than those of the ordinary shape, as they would not strike a direct but a glancing blow. These blades are tapered on both the leading and after edges, and when in rotation, whether turning ahead or astern, may be said to form a cone that will throw off any passing wreck chain or cordage without fouling or injury; a coil of rope falling upon this screw would be instantly thrown off. This form of blade will also insure a more constant and equable action on the water under all circumstances, and thereby reduce vibration. It may be applied to vessels of very light draught for river purposes half immersed, as in many American river and lake steamers.

Method of Attaching Propeller to Shaft.—The method of attaching it to the shaft, as shown in Plate I., fig. 5, enables it to be readily shipped and unshipped, and being comparatively light, the after bearing is dispensed with, part of the after length of the screw shaft into which the short shaft of the propeller is shipped, being of increased diameter, so as to give a sufficient bearing to prevent the weight of the screw wearing unduly, and to admit of being bored out to receive the short shaft attached to the propeller, which is secured by a key, gib, and cotters; by this means the screw and short shaft may be removed without disturbing the main shaft or admitting water into the ship.

It will be seen by the drawings that the part known as the "dead wood" in timber-built ships is dispensed with, and with it all the cumbrous and costly paraphernalia of stern-posts, screw-lifting frame, and, in fact, every forging of any consequence, thereby reducing the weight of the after extremity, and the cost of the ship. There being no aperture for the screw, the after section will be stronger and lighter.

Two Screws advocated.—As before stated, I advocate two screws (of the form and character described) having three or four blades; these are fitted to cylindrical trunks, G, under either quarter, which connect the keels with the counter of the ship; these trunks are the same diameter as the boss of the screws, against which they fit closely, so as to prevent anything getting between them, the rudders, H, being attached to the after extremity of the keels, but before and lower than the screws, so that both screws and rudders are quite clear of each other, and are thus capable of performing their respective functions without hindrance, both being immersed at such a depth as to place them entirely out of reach of shot or ram, and prevent their being lifted out of water. Should it be found that these rudders are too close to the screws and impede their action, they may be placed further forward, which will rather increase the steering power than otherwise. It will be seen that by this method of fitting the screws, the water being already displaced by the ship and trunks, it comes direct to the screw-blade and closes by its own gravity

on the cycloidal boss, leaving no appreciable vacuum, whereas in the ordinary mode the boss not only displaces a large volume of water, but leaves a considerable vacuum in its wake, which will absorb power, retard speed, and, I am inclined to believe, cause vibration.

Manœuvring.—Being right and left screws, they turn in opposite directions, and therefore correct that deviation from a right line either would produce separately (as is well known); thus, the helm is not required to counteract that effect; there is, consequently, less obstruction to the ship's way. By reversing either screw the ship may be turned rapidly by *the screws alone* to starboard or port on her centre, or nearly so (as with two sculls in a boat, one backing and the other pulling), and may be steered, going ahead or astern, by these screws, *without any assistance from the helm, in the most accurate manner.* This I have seen accomplished so perfectly, that there can be no doubt of success if properly fitted. The absence of the after stern-post and dead wood, combined with the reduced immersion, will materially facilitate manœuvring, there being considerably less area of resistance, and under any circumstances, whether stationary, at slow or at quick speed, a vessel thus equipped will answer her "screw" instantly, and not only take up, but retain, her position, no matter what the circumstances.

These screws, having their centres much lower than a single screw of the same calculated power, will work uniformly in water of greater density, be far less liable to accident, and, being constantly immersed, will, it is believed, give a result beyond that of a single screw of the usual character. Their size, and the speed at which they are driven, will, of course, be determined by the required speed of the ship. Moreover, both screws and rudders are in a more favourable position for working, being not only constantly immersed, but well removed from the centre of the wake where the water is broken, and there is an eddy or swirl caused by the water closing in from both sides the dead wood, which increases with increased speed.

Rudders.—The rudders are geared together as at I in Plate III., and worked by steam or by a wheel on deck, or in the after part of the engine-room, so that in action the engineers and helmsmen receive orders simultaneously, helm and screws acting together on the instant, helmsmen and steering apparatus being out of reach of shot. I submit that such a combined power of steering would give great advantage to a ship in action, or in narrow seas, over one with one screw, "which would go" against the helm, whichever way her bow "happened to take," whether from the force of wind or current.

Non-Lifting Screws.—In this method of fitting the screws no provision is made for lifting them, it being considered unnecessary, for, in the first place, it is not at all probable that large under-rigged ships would be allowed to depend on sails alone, particularly on special service; and if making a passage the screws could be disconnected or driven by the donkey engines at a speed to overcome friction. I question much if they would make any material difference if not driven; at all events, not much in excess of the resistance now offered by the after stern-post, which must retard very considerably. In this opinion I am supported by the reports of many captains of screw steamers. In smaller vessels and gunboats

these screws might (as we propose to fit them) be readily unshipped and hoisted in over a bill-board on each quarter; the passage could be thus made as a sailing vessel, and the screws easily reshipped when necessary without docking.

Gunboats of very Light Draught.—As the utility of efficient gunboats of very light draught is now beyond all question, I consider this method of constructing them would be attended with many advantages, especially in ascending rivers, where they are constantly liable to ground, or defending our own coast; the keels, as before described, also giving sufficient strength and stability to make a sea voyage; but, unless some very decided alteration takes place in the construction and arrangement of boiler, no considerable reduction can be made in the draught of our gunboats.

Their Boilers.—Some of these vessels have two sets of low-pressure boilers, one reaching nearly to the deck for ordinary purposes, styled "working boilers," which, being exposed to shot, cannot (are not intended) be used in action. The other set, placed lower, but occupying greater fore and aft space, are called "fighting boilers." These, at their best, cannot generate more than sufficient steam to propel the vessels nine knots; whereas, if a suitable form of high-pressure boilers were used, fitted with a surface condenser, they would occupy even less space than the "fighting boilers," do the work more effectually, and leave the space and displacement now occupied by the working boilers for coal or any other purpose. The form of high-pressure boiler, and the method of connecting it with the uptake described hereafter, would be well adapted for this purpose. The engine would also be far lighter and more readily handled than those now in use, especially if fitted with wrought-iron framing.

High-Pressure Steam.—That steam at high pressure with surface condensation must be eventually adopted in war steamers is so universally admitted by engineers, that any remarks I might offer would be superfluous, beyond the fact of Mr. Roberts having constantly urged the adoption of both in his patent, and on many public occasions.

Engines.—As the screws will be driven at a higher speed than a single screw of large diameter, it is proposed to use gearing (direct action, if preferred, being equally applicable), each shaft being driven by two horizontal high pressure engines, K, with surface condensers, P, and multitubular cylindrical boilers, N, the whole of which, including the gearing, will be considerably lower than those in use at present in deep draught ships, and, consequently, less exposed to shot. By this arrangement the huge engines now in vogue would be divided into four smaller ones, lighter, less liable to accident, more readily replaced or repaired, and less costly; duplicate parts may also be carried with facility. The cylinders on the starboard side work the port screw, and *vice versa*, so that a long stroke is obtained. In the ship of 5,000 tons, Plate II., the stroke is 5 feet. By placing the boilers and machinery, as shown in the drawing, the screw shafts L and steam-pipe M are considerably shortened. The framing of the engines is of wrought iron, and therefore lighter than when composed of cast; it is secured to the ship in such a manner as to add to the strength, and, being of wrought iron, is better calculated to

resist concussion should the ship be employed as a ram, or receive the blow of one.

Boilers.—The type of boiler recommended is that proved by long and successful experience to be well adapted for "high pressure," and has been carefully considered and arranged to suit sea-going purposes, every part being strong and easy of access.

It will be observed that they are arranged in two sets, which may be worked singly or otherwise. Mr. D. K. Clark's clever adaptation of the steam jet to promote draught and combustion, entirely preventing smoke, would be specially applicable to these boilers. It assists materially in getting up steam, and, from the absence of smoke, would prove invaluable in a strategic point of view. This invention effects a considerable saving in fuel (an important fact where every ton of coal is of such vital importance), and facilitates the use of all inferior descriptions of fuel.

With this arrangement the furnace of these boilers may be banked up in the most perfect and economical manner, the steam being kept to almost any required pressure, and got up in the least possible time if required suddenly.

These cylindrical boilers may be readily removed for examination or repair, and when clothed with non-conducting material will lose little heat by radiation; should they require extensive repair or removal they may be taken up the hatchways between the funnels, instead of breaking up the deck, as is now the case, in removing the old low-pressure boiler, the hatchways giving light and air, which are so much needed, even in temperate climates.

Funnels.—The arrangement for the "uptake" of the furnaces, O, allows one boiler to be cut off without interruption to the remainder; the cellular casing, O′, around the funnel, will ventilate and lower the temperature of the boiler-room, besides giving additional support and protection to the funnel. Instead of the stokers being between two long rows of furnaces, they stoke from opposite sides, which must necessarily improve their condition. This I consider a very important point, for good stokers are rare; their lot should therefore be improved to the utmost. More depends on good stoking than is generally supposed, and it often happens that what the engineer saves in the engine-room by care and attention during forty-eight hours may be lost in twelve in the stoke-hole by negligence or ignorance.

Coal Bunkers.—The coal bunkers, E, on either side the boiler and engine-rooms, and athwart ships (as shown in the drawings), will add to the security of both, defending them from any shot that may either penetrate the armour-plating or strike below it.

The plan of fitting the coal bunkers, E (as shown in all the drawings), forms an important feature in the cellular system, and adds materially to the longitudinal strength, so specially requisite in light-draught ships, in which "the beam" is of decreased depth.

The coal bunkers in large ships may be filled expeditiously by means of small carriages running on a tramway, the cells being made to communicate with one another, so that the coals can be readily removed if required.

In this cellular arrangement much coal trimming will be dispensed with,

as coal may be taken from any required cell of the bunker without the remainder shifting.

Although the advantages of this principle have been generally admitted, it has been only partially adopted in some instances, but never carried out in its integrity.

Surface Condensers.—The surface condensers are in two sets; as proposed in the specification, they are constructed and arranged in a series of cylinders, either of which may be removed for cleaning or repair without impeding the action of the remainder; they are placed abaft the engines on the incline of the run (as shown), extending to the light water line, the opening for the ingress and egress of water being made in the bottom of the ship. This arrangement, as well as several others connected with the steerage, ventilation, &c., though scarcely inferior in importance to many points mentioned, cannot be clearly shown on so small a scale, but will be cheerfully shown and described on application.

Method of Stepping and Securing Masts.—The method of stepping and securing the masts will add materially to the strength and rigidity of that part of the ship which is now the weakest, viz., the partners. In place of being stepped on the bottom, as is usual, every deck and neighbouring beam bears its portion of the strain, the lower or housed part of the mast being built to the transverse iron bulkheads, as at Q, Plates I. and II., thus forming literally a part of the ship, the wrought-iron knees indicated being strong supports to the deck. The upper part thus built in, projects above the upper deck, the mast stepping over it and resting on a strong iron flange or collar let in to the deck, and firmly bolted together with two rows of bolts or rivets; by this plan a mast might be cut away readily, and the part built into the ship remaining may be used as a step for a wood or jury mast.

Masts and Sails.—I propose to have four masts so disposed that the ship may be manœuvred without head-sails on a bowsprit, as I consider that appurtenance not only superfluous, but ill adapted for war purposes, especially if used as a ram.

The lower masts are of iron; the topmasts and topgallantmasts of wood are in one, the topmast rigging being fitted on a funnel, so that when necessary to strike the masts on steaming against a head wind or in action, they may be lowered down through hatches cut in the deck to receive them (the funnel and rigging being deposited on the lower caps and secured there), and hove up again, without starting the lanyards, by powerful grooved windlasses on the lower deck specially adapted for the purpose.

Should royal-masts be considered necessary, they may be fitted abaft all, as shown in Plate II.

The spars and sails on the two middle or mainmasts are all the same size and form, as are likewise those on the fore and mizen-masts, the only difference being in the height of the lower masts; on them large fore and aft sails may be set, with gaff-topsails over, but I should infinitely prefer staysails, which, if properly cut and set, are better and handier sails aloft.

Labour-saving Machinery.—As it is of the utmost importance that every contrivance should be resorted to that may reduce weight, economise space, and save labour, I advocate a more extended use of simple mecha-

nical contrivances than has heretofore been the custom, and if the reduction in the crews that has been spoken of is carried out in consequence of decreased armament, "labour-saving machinery" must be be adopted; hence, the windlass applied for striking and fidding topmast.

Windlass.—As another means of effecting this, I recommend the windlass shown in Plate III., W, which may be worked by hand or steam, the principle of which has been amply tested in a variety of shapes.

This windlass may be readily applied as a substitute for one or both the capstans now in use. It is calculated to prevent the accidents so often occurring by the capstan throwing the men over the bars. When once brought to the windlass, *all handling the chain is done away with;* it being purchase, bitts, and stoppers combined; bitting, unbitting, and ranging the chain, are entirely dispensed with—a very obvious advantage in using the heavy chains now necessary in large-class ships. All jerks and strains now experienced in veering, letting go, and riding at an anchor, are obviated, and the cable is ready for veering, letting go, or heaving in, at a moment's notice (messengers, nippers, and stoppers being dispensed with), the chain being under perfect control of the powerful brake attached to it. It occupies far less space than the present capstan with the bars shipped, and may be used for any purpose on board, being not only a powerful steady purchase for lifting heavy weights, such as guns, boilers, &c., but lowers them steadily without jerking, as must be the case in lowering round a capstan, &c., where surging is necessary. It is also well adapted for sheer falls, and all other purposes of a similar character, where great steadiness and regularity in hoisting and lowering are required, and may work any length of chain without riding turns. The advantage such a windlass will give in veering in a gale over the present inefficient and uncertain mode is too obvious to need comment.

Light-Draught Coast Defence Ships.—Descriptions of plans and sections of a light-draught coast defence ship, of about 2,300 tons, length 240 feet, breadth 45 feet, draught 15 feet, mounting 14 guns, 8 feet 6 inches above the water.*

No. 1 is a general exterior view, showing a proposed method of protecting the guns by inclined armour-plated sides, rounded from the deck upwards, terminating in a rounded platform or deck; the top sides forward and aft being fitted to lower when bow or stern guns are used.

2. Deck plan, showing a method of giving ventilation and light, and relieving the gun-deck from smoke by a strong iron grating, R, in which are hatchways for giving access to the deck, for boarding or repelling boarders.

R R are other hatchways, similarly fitted for ventilation and access to other parts of the ship.

3. Longitudinal section, showing internal arrangements.

T. Bread and dry provision room.

K. Engine room.

E. Athwart ship coal bunkers.

* This model was designed by us to meet conditions suggested by Rear-Admiral George Elliot, and submitted by him to the Admiralty and War-Office, in June, 1861.

N. High-pressure cylindrical boiler, with method of fitting the uptake to funnel, and the cellular casing round the funnel to give ventilation in the boiler room—same arrangement round masts to ventilate between decks. The funnel is telescopic; when run down projects only three feet above the deck in action, which is protected, the draught being given by the apparatus described, which also prevents smoke.

U. The magazine.

V. Chain locker.

W. Windlass, described previously.

X. Form of stem for receiving the prow of ram, and method of strengthening the bows to resist the shock, being a series of short decks or breast hooks.

4. Arrangement of longitudinal bulkheads, forming cellular girder, with the side applied as coal bunkers, water tanks, and other purposes.
5. Stern view, showing propellers, and three stern chase guns, with gunwale lowered on starboard side.
6. Section in engine room, showing proposed arrangement of engines, K; coal bunker, E; with cellular bottom and keels, C, D.

This vessel is intended for the defence of harbours, or to cross the Channel if required, being quite capable of taking the sea, and may be rigged either as a schooner or polacca. She is fitted to act as a ram, and, from her great longitudinal strength, imparted by the peculiar mode of construction described, is, I conceive, specially adapted for that purpose, as also from the fact of the two screws giving her the power of turning in her own length, and, being steered by them, going ahead or astern without assistance from the rudders; in fact, under steam the rudders are unnecessary.

Armament.—I propose to arm this vessel with 14 guns, two of which are to be of very heavy calibre, one forward and the other aft, being bow and stern chasers, firing in a line with the keel, as shown in the drawing. The guns on either side may be fired in the same direction, or as broadside guns, by shifting them, there being spare ports for the purpose. Thus, three guns can be brought into action, whether chasing or retiring, and six on the broadside.

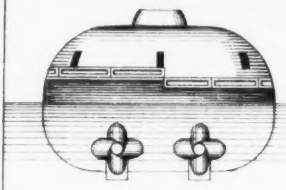
The cellular keel and bottom will allow sufficient water to be admitted to immerse the ship from a foot to eighteen inches; thus one foot of armour-plating might be dispensed with, and a smaller mark displayed to the enemy.

This plan of defending the guns, in addition to the advantage of having a battery of three guns forward and aft, will reduce the weight of hull and armour-plates.

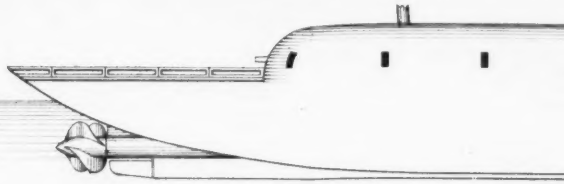
Smaller vessels on this plan, drawing 10 feet of water, and mounting four guns, might be very effectively employed in rivers, small harbours, and creeks, they being capable of grounding without injury, and when grounded being upright. Moreover, such a shield vessel, having the power of turning as described, would become "the turntable," and thus bringing the guns into action as required, an incessant fire might be kept up. All attempt at accommodation in the usual acceptation of the term should be abandoned in such vessels, they not being required to go to sea.

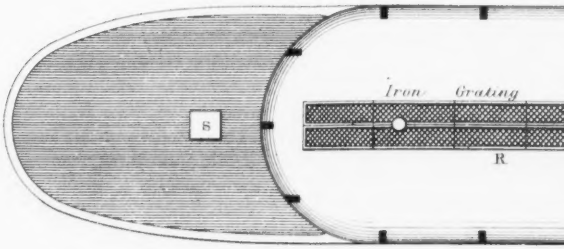
ARMOUR PLATED LIGHT DRAUGHT COA

Fig. 5.



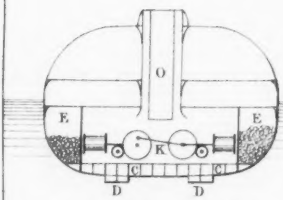
Stern View.



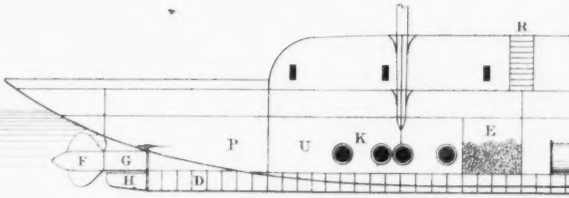


Plan

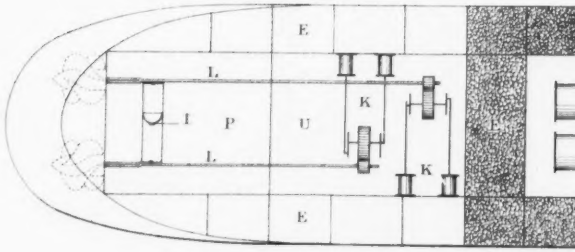
Fig. 6.



Transverse Section.



Longi

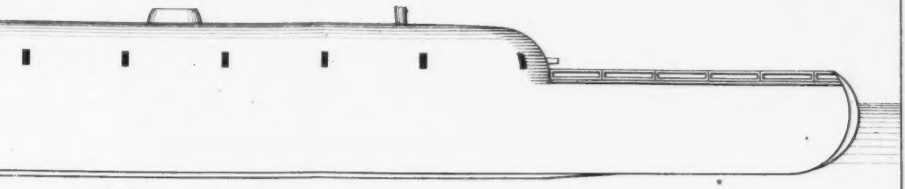


F

Scale 1/32 of an Inch to a Foot.

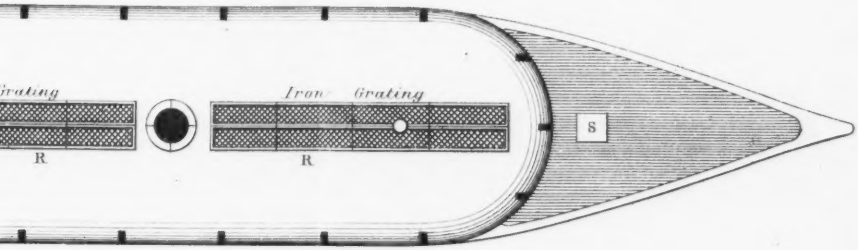
UGHT COAST DEFENCE SHIP. 14 GUNS.

Fig. 1.



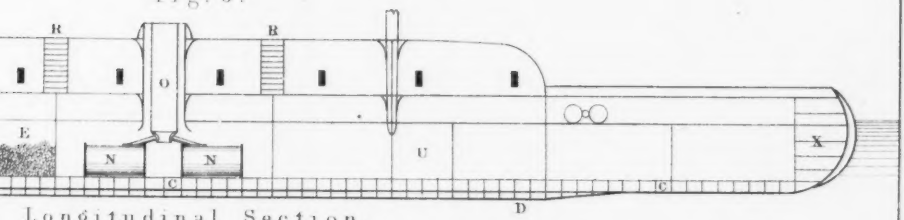
Elevation.

Fig. 2.



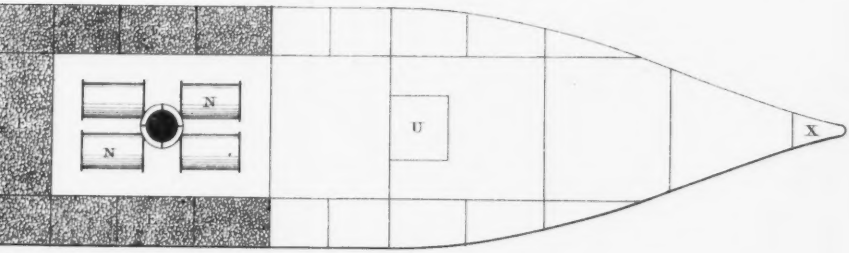
Plan of Upper Deck.

Fig. 3.



Longitudinal Section.

Fig. 4.



Floor Plan.

Designed by R^d Roberts C.E. and Commander T.E.Symonds R.N

J.R.Jobbins

Duplicate Arrangements.—In conclusion, I beg to call attention to the fact that in all the arrangements I have described there is a *duplicate of every principal part*, so that in the event of one breaking down, the ship may never be totally disabled, except under very extraordinary circumstances. This will, I believe, be admitted by sailors (and it is to them more especially I address myself) to materially enhance the efficiency of a steamship of war of whatever description.

And I may add that the models and plans I have exhibited and described are not suggested by the results of recent experiment, but that they were for the most part prepared long previous to the now well-known proportions of iron-cased ships being published. Never having had access to the weights and quantities required for ships of that class, we may have possibly erred in some of the proportions, but they may be readily altered to suit special cases, the principles of construction and the method of steering and manœuvring being applicable to all.

Models of these vessels may be seen at the Naval Department of the International Exhibition, Class 12, and at 10, Adam Street, Adelphi.

Mr. SAMUDA: I have no remarks to make in general upon this paper. It is new to me as I hear it. A few things I feel certainly bound to say with regard to it. The description of rudder does not come before me as new. I have had through my hands vessels with similar rudders to those, and I am bound to say they were not at all satisfactory.

The CHAIRMAN: Was it from their position? Before or behind the screw?

Mr. SAMUDA: They did not act well. I think it is not at all impossible that the position relatively to the screw may have acted very much to their disadvantage. Instead of getting the benefit of the water washing up to the rudders, the water came to them before they had the benefit of being pushed further by the screw. Certainly, the result of steering equally well forward and aft, as contemplated in this paper, was not at all realised in these vessels. My first acquaintance with these vessels was this: they were brought to me to have their rudders taken out, because they were not found suitable. We took them out, and put in ordinary rudders behind the stern-post. I do not condemn them, I merely state the fact as it occurred. With regard to the screw itself, I would ask whether the inventors have had sufficient experience in that length of blade, which they have got there, to find that they get as good a mechanical result as we do in those proportions which experience has shown us, at least with our present knowledge, to be the best? We find that if we depart very much from the proportions which have been arrived at by practice, that the effect is something extraordinarily bad. Just to give an illustration. Assuming that one-sixth of the length or pitch of the screw is considered a very good proportion in a large sized screw, in a smaller sized screw one-eighth is found to be so. I recollect a circumstance of having no less than five vessels built all off precisely the same lines, and of having a variation to the extent of two of them being one-eighth of the length, which produced a very good result to the ship. One of them, under the impression that a much better result was going to be obtained, particularly in heavy weather, as it was stated, by giving greater surface to the screw, having been subsequently made something over one-sixth, we lost a knot and a half out of the vessel; the same engines, made by the same man, the ship's form precisely the same, the lines in every respect the same. Cutting the screw brought the vessel back again to exactly the same condition as her sister vessels. Therefore this is a thing which ought to be well considered before it is put forward. Then, all our experience goes to the absolute necessity of doing away with the gearing. Gearing is a thing of past times. It was introduced, and it was used very extensively, when screws were first put forward; for the simple reason that people were

not prepared to make engines go, not prepared to think that they could go at the speed at which it has since been found it is not only advisable to drive them, but at which they can be driven and kept in ordinary and fair repair. But with the expense of maintaining gear, the noise accompanying it, the uncertainty of breaking the teeth, and all these sort of things, certainly it is looked upon by all mechanics as having been a very fortunate day for screws when a sufficient amount of perfection in the manufacture of engines has been arrived at to enable gearing altogether to be done away with. Therefore those points do not appear to me to be walking in the direction of improvements. How far the other points of the invention may bear, such as the double keel, I do not profess to know anything about; I have not had experience of them. With respect to double screws, I must say that my experience is very unfavourable to them. I was always led to suppose that in shallow draught of water double screws performed very much more than single screws; but within the last two years I have made a number of vessels for the Spanish Government, fitted with double screws, but we did not find the increased speed from them which we had got under similar circumstances with single screws. We found this disadvantage, that when we were attempting to turn with double screws we literally stopped the way of the vessel. Putting the helm over, so completely blocked the passage of the water from the screw opposite to which the rudder was turned, that we brought the vessel up from nine knots an hour to something like three. It was exactly the same as if that screw was working at mooring, and a corresponding disadvantageous result was obtained on the vessel. Altogether I came to the conclusion that double screws had nothing like the advantage of a single screw of larger diameter, placed in the dead wood of the vessel. Even though a portion of that screw is out of the water, yet you will perceive that the surface of the single screw below the water is very much in excess of that which the two screws give together when wholly submerged. I merely mention these things to the inventors for their consideration, that they may turn their attention to them and see how far they may be able to realise all the expectations which they have put before us.

Captain COLLINSON, R.N., C.B.: With respect to the double screws, I may say I was in Canada last year, and I had the opportunity of seeing a great many propellers with double screws. On conversing with the people, they came to the same conclusion that Mr. Samuda has. They said they were going to put in no more double screws; they had tried them both at the sides and at the stern, and in neither case did they answer so well as the single screw.

Captain SYMONDS: In answer to what Mr. Samuda has said about gearing, I would say that Mr. Roberts prefers that mode of applying the power; because in driving small screws to make them equal to larger screws, of course they will have to be driven at considerably higher speed; and knowing that there has been an objection to driving a piston at a very high speed, he introduces the gearing to relieve the engine. I may add that it is quite as possible to drive direct in this case as it is in the others. But with respect to the double screws, and to what he said about the rudder, I apprehend that the rudder he refers to was a rudder placed in the old style; and that the two screws he was speaking of were placed one on either side the dead wood, the rudder being between them.

Mr. SAMUDA: Yes.

Captain SYMONDS: Exactly so; and in the course of my observations I mentioned that that was one of the objections that had been raised to two screws, that there was not sufficient space, with the dead wood existing, to leave the screw sufficient space to work; also that the water was so confined by the dead wood that it was almost impossible to use them effectively. It is for that reason that we do away with the dead wood entirely. Now, I beg to submit that these two screws are under very different conditions to the two screws which Mr. Samuda spoke of, with the dead wood running between them, and the rudder abaft it. I can quite imagine that if there was the dead wood running down between, and the rudder being immediately abaft them, it would, of course, whenever the rudder was shoved over, have exactly the effect on the screws he has described. But in this case the rudders are below and before the screws, and, as I mentioned, they both act independently of one another—the water coming as fairly to one as to the other—so that I do not agree with him, that because they did not answer in the case he mentioned, they should not answer in this. I do not think the conditions are at all the same.

The CHAIRMAN: Have you got any account of experiments that have been tried?

Captain SYMONDS: No, there have been no experiments with these vessels. Experiments which I have seen with a vessel with screws somewhat similar to these were certainly very satisfactory. She was a very light-draught vessel, as I have described, with a long

shallow rudder. They never appeared to interfere with each other; they never touched one another; and she readily turned round in her own length without moving the rudder.

Mr. SAMUDA: Where was that rudder placed?

Captain SYMONDS: That rudder was placed in the ordinary manner; and, certainly, the steering was most perfect with the screws alone, as I described it. However, I can quite understand what Mr. Samuda's objection is to the two screws, generally, with the dead wood between them. This is a totally different case, and also with the rudder. In the rudder that Mr. Samuda spoke of as being altered, I am quite aware that that is the case. I believe he is not the only person who has altered a vessel of that description; but I think Mr. Samuda will say that the rudder was not placed as this is.

Mr. SAMUDA: I think so.

Captain SYMONDS: Not in the same position with the screw.

Mr. SAMUDA: Precisely.

Captain SYMONDS: Was it, with regard to the screw?

Mr. SAMUDA: Precisely.

Captain SYMONDS: Under it, or before it?

Mr. SAMUDA: Before it, not under it; yours is not under it.

The CHAIRMAN: The two rudders?

Mr. SAMUDA: No; there was one rudder and one screw. But I must be understood as not wishing at all to say anything in derogation of the invention. I am only calling attention to these points to prevent mistakes being made, if by experience they can be guarded against. What I intended to convey was: first, that the rudder, placed precisely in a similar position to the screw as one of those you represent, has come before me in one instance in a vessel with the screw and the rudder, and has been found quite inefficient. It was not only in one instance, but in two. There were two vessels brought to me to be altered, because they would not steer. The pilots had taken a great deal of pains, and one a great deal of expense, before they were brought to me. Therefore, I wanted to convey to you, so far as my experience went, that that portion of the invention was bad; that is to say, not likely to be successful. Therefore, if that portion was obliged to be abandoned, the other that would be left to you, would be to put the rudder in the ordinary place, and with two screws my experience shows that to that extent it was not satisfactory.

Captain SYMONDS: I still maintain that the rudder in the case mentioned not answering does not condemn this; because, in the first place, that was a single rudder in the centre, and these two are at the side, and there are, therefore, two surfaces acting instead of one. I believe the reason why one or two of those vessels which Mr. Samuda mentioned did not steer, was because they had not sufficient rudder to steer with. That is what I have generally understood. However, I am obliged to you for mentioning the matter; of course, it will make one look more closely to the subject. At the same time I hope before long to be able to show you a vessel which will probably do away with the impression which you appear to have.

The CHAIRMAN: The subject is very important. We were very much at sea when the screw was first introduced. With a little change in the pitch of the screw there is an extraordinary difference of result, and we are not able to explain why it is. It certainly is very important with long ships that they should be able to turn with facility; if it could be arrived at, one would desire to see it very much. No doubt, it is puzzling to conceive that two screws will give so great a result as one with a very much larger diameter. I do not understand it myself; yet, seeing how our preconceived opinions are overturned every day, one cannot undertake to say that it will not do so. Many persons object to the rudder being so far forward, and they think the effect is not so great. I have long thought the very reverse of that. I think a rudder placed so far at the extremity, so long a distance from the turning point, is injurious. I believe the further aft the centre of gravity is towards the rudder, the more quickly the vessel turns; so, in bringing the rudder towards the centre of gravity, the same thing would happen. I do not think it is from the position of the rudder—I mean relatively to the centre of gravity—that the defective steerage would arise; I think it would be much more likely to arise from the screw. It does not, as in ordinary screw vessels, come upon the rudder to increase and intensify the action of the rudder. Therefore, I think the position of the rudder there would not be so good as in an ordinary screw vessel by a large amount. Of course, the action of the keel is very useful in retarding the rolling motion; but still, at the same time, I think it is rather the introduction of another evil, in some respects, to reduce an existing evil. Such, for

not prepared to make engines go, not prepared to think that they could go at the speed at which it has since been found it is not only advisable to drive them, but at which they can be driven and kept in ordinary and fair repair. But with the expense of maintaining gear, the noise accompanying it, the uncertainty of breaking the teeth, and all these sort of things, certainly it is looked upon by all mechanics as having been a very fortunate day for screws when a sufficient amount of perfection in the manufacture of engines has been arrived at to enable gearing altogether to be done away with. Therefore those points do not appear to me to be walking in the direction of improvements. How far the other points of the invention may bear, such as the double keel, I do not profess to know anything about; I have not had experience of them. With respect to double screws, I must say that my experience is very unfavourable to them. I was always led to suppose that in shallow draught of water double screws performed very much more than single screws; but within the last two years I have made a number of vessels for the Spanish Government, fitted with double screws, but we did not find the increased speed from them which we had got under similar circumstances with single screws. We found this disadvantage, that when we were attempting to turn with double screws we literally stopped the way of the vessel. Putting the helm over, so completely blocked the passage of the water from the screw opposite to which the rudder was turned, that we brought the vessel up from nine knots an hour to something like three. It was exactly the same as if that screw was working at mooring, and a corresponding disadvantageous result was obtained on the vessel. Altogether I came to the conclusion that double screws had nothing like the advantage of a single screw of larger diameter, placed in the dead wood of the vessel. Even though a portion of that screw is out of the water, yet you will perceive that the surface of the single screw below the water is very much in excess of that which the two screws give together when wholly submerged. I merely mention these things to the inventors for their consideration, that they may turn their attention to them and see how far they may be able to realise all the expectations which they have put before us.

Captain COLLINSON, R.N., C.B.: With respect to the double screws, I may say I was in Canada last year, and I had the opportunity of seeing a great many propellers with double screws. On conversing with the people, they came to the same conclusion that Mr. Samuda has. They said they were going to put in no more double screws; they had tried them both at the sides and at the stern, and in neither case did they answer so well as the single screw.

Captain SYMONDS: In answer to what Mr. Samuda has said about gearing, I would say that Mr. Roberts prefers that mode of applying the power; because in driving small screws to make them equal to larger screws, of course they will have to be driven at considerably higher speed; and knowing that there has been an objection to driving a piston at a very high speed, he introduces the gearing to relieve the engine. I may add that it is quite as possible to drive direct in this case as it is in the others. But with respect to the double screws, and to what he said about the rudder, I apprehend that the rudder he refers to was a rudder placed in the old style; and that the two screws he was speaking of were placed one on either side the dead wood, the rudder being between them.

Mr. SAMUDA: Yes.

Captain SYMONDS: Exactly so; and in the course of my observations I mentioned that that was one of the objections that had been raised to two screws, that there was not sufficient space, with the dead wood existing, to leave the screw sufficient space to work; also that the water was so confined by the dead wood that it was almost impossible to use them effectively. It is for that reason that we do away with the dead wood entirely. Now, I beg to submit that these two screws are under very different conditions to the two screws which Mr. Samuda spoke of, with the dead wood running between them, and the rudder abaft it. I can quite imagine that if there was the dead wood running down between, and the rudder being immediately abaft them, it would, of course, whenever the rudder was shoved over, have exactly the effect on the screws he has described. But in this case the rudders are below and before the screws, and, as I mentioned, they both act independently of one another—the water coming as fairly to one as to the other—so that I do not agree with him, that because they did not answer in the case he mentioned, they should not answer in this. I do not think the conditions are at all the same.

The CHAIRMAN: Have you got any account of experiments that have been tried?

Captain SYMONDS: No, there have been no experiments with these vessels. Experiments which I have seen with a vessel with screws somewhat similar to these were certainly very satisfactory. She was a very light-draught vessel, as I have described, with a long

shallow rudder. They never appeared to interfere with each other; they never touched one another; and she readily turned round in her own length without moving the rudder.

Mr. SAMUDA: Where was that rudder placed?

Captain SYMONDS: That rudder was placed in the ordinary manner; and, certainly, the steering was most perfect with the screws alone, as I described it. However, I can quite understand what Mr. Samuda's objection is to the two screws, generally, with the dead wood between them. This is a totally different case, and also with the rudder. In the rudder that Mr. Samuda spoke of as being altered, I am quite aware that that is the case. I believe he is not the only person who has altered a vessel of that description; but I think Mr. Samuda will say that the rudder was not placed as this is.

Mr. SAMUDA: I think so.

Captain SYMONDS: Not in the same position with the screw.

Mr. SAMUDA: Precisely.

Captain SYMONDS: Was it, with regard to the screw?

Mr. SAMUDA: Precisely.

Captain SYMONDS: Under it, or before it?

Mr. SAMUDA: Before it, not under it; yours is not under it.

The CHAIRMAN: The two rudders?

Mr. SAMUDA: No; there was one rudder and one screw. But I must be understood as not wishing at all to say anything in derogation of the invention. I am only calling attention to these points to prevent mistakes being made, if by experience they can be guarded against. What I intended to convey was: first, that the rudder, placed precisely in a similar position to the screw as one of those you represent, has come before me in one instance in a vessel with the screw and the rudder, and has been found quite inefficient. It was not only in one instance, but in two. There were two vessels brought to me to be altered, because they would not steer. The pilots had taken a great deal of pains, and one a great deal of expense, before they were brought to me. Therefore, I wanted to convey to you, so far as my experience went, that that portion of the invention was bad; that is to say, not likely to be successful. Therefore, if that portion was obliged to be abandoned, the other that would be left to you, would be to put the rudder in the ordinary place, and with two screws my experience shows that to that extent it was not satisfactory.

Captain SYMONDS: I still maintain that the rudder in the case mentioned not answering does not condemn this; because, in the first place, that was a single rudder in the centre, and these two are at the side, and there are, therefore, two surfaces acting instead of one. I believe the reason why one or two of those vessels which Mr. Samuda mentioned did not steer, was because they had not sufficient rudder to steer with. That is what I have generally understood. However, I am obliged to you for mentioning the matter; of course, it will make one look more closely to the subject. At the same time I hope before long to be able to show you a vessel which will probably do away with the impression which you appear to have.

The CHAIRMAN: The subject is very important. We were very much at sea when the screw was first introduced. With a little change in the pitch of the screw there is an extraordinary difference of result, and we are not able to explain why it is. It certainly is very important with long ships that they should be able to turn with facility; if it could be arrived at, one would desire to see it very much. No doubt, it is puzzling to conceive that two screws will give so great a result as one with a very much larger diameter. I do not understand it myself; yet, seeing how our preconceived opinions are overturned every day, one cannot undertake to say that it will not do so. Many persons object to the rudder being so far forward, and they think the effect is not so great. I have long thought the very reverse of that. I think a rudder placed so far at the extremity, so long a distance from the turning point, is injurious. I believe the further aft the centre of gravity is towards the rudder, the more quickly the vessel turns; so, in bringing the rudder towards the centre of gravity, the same thing would happen. I do not think it is from the position of the rudder—I mean relatively to the centre of gravity—that the defective steerage would arise; I think it would be much more likely to arise from the screw. It does not, as in ordinary screw vessels, come upon the rudder to increase and intensify the action of the rudder. Therefore, I think the position of the rudder there would not be so good as in an ordinary screw vessel by a large amount. Of course, the action of the keel is very useful in retarding the rolling motion; but still, at the same time, I think it is rather the introduction of another evil, in some respects, to reduce an existing evil. Such, for

instance, as introducing the keel to stop the rolling in the "Warrior," putting bilge-pieces. These are mere makeshifts, and ought not to be necessary. I believe if we were to experiment and investigate we should be able to build ships without having recourse to these makeshifts to improve their qualities afterwards. However, I think we are very much indebted to Captain Symonds for having brought forward this subject, and I am sure you will allow me to return our thanks to him.

Mr. ROBERTS: With reference to Mr. Samuda's remarks about the screw, let me say this screw begins at a favourable angle to propel (45 degrees), on account of the largeness of the boss. The area of one of these blades is 15 feet; the whole of them would be 60 feet; and as there are two screws, they give together a surface of 120 feet. Whereas a propeller, for the same purpose, has not above 80 or 90 feet. With regard to gearing, if gearing be properly made, it will last indefinitely long; it only depends on the make. But if you do not like gearing, you may use friction wheels; they will not make much noise.

Mr. SAMUDA: They have been found very objectionable indeed. A little oil pouring on them will spoil them altogether.

Mr. ROBERTS: There are many mills in England that have gone many years with them.

Mr. SAMUDA: They do not put so much power through them as they do in the screws.

Mr. ROBERTS: However, gearing, if well made, will last indefinitely long; I say I can make a pair that would certainly go for forty years.

Captain SYMONDS: Those in the "Great Britain," for instance.

The CHAIRMAN: I think you should observe that the resistance which this offers is only equal to the diameter of the cone. It is a question of introducing a multiplicity of blades. You increase your surface by increasing your blades; but that does not increase the resistance to the amount given by the one screw of greater diameter.

Captain SELWYN, R.N.: I should like to say a few words to Captain Symonds upon this subject. I have found, on studying attentively the action of screws as shown in water, and all the old conditions under which Mr. Napier and others have put in two or more screws, that they have generally failed, simply because the ordinary view of the action of the screw in water is that it acts against and throws off a column or cylinder of water. Now, what the screw really does, is to throw off, and, therefore, act against a truncated cone of water, partly caused by the centrifugal action set up by the revolution of the screw. There is, therefore, a compound force producing, not a cylinder but a peculiarly shaped truncated cone. Now, under these conditions, you cannot put in two screws parallel and close to each other with good effect; the two cones crossing each other invariably and seriously deduct from the resistance of the water. In one of the floating batteries, three of these small screws were put in, one in the centre in the usual place, the other two under the counters, with parallel shafts. The result was not good. It was found afterwards, on lifting out the two side screws and leaving the centre one, that the same speed was obtained as with the three; but that was only from the cause I have before pointed out. Had those two outside screws been placed widely apart, or at divergent angles, you would then have had the full effect of all the screws, minus the deduction (in the case of the divergent ones), due to the parallelogram of forces, as every one knows who has studied that theory. But of course no one will ever attempt to prove that two one-inch pipes are equal to one two-inch pipe, or that two screws of ten feet diameter can ever be equal to one screw of twenty feet diameter. It would be an utter fallacy. The area of push, from which you derive your motive power, would be, of course, very much lessened. I need not say that my impression is, that if you get two screws of the full size due to the draught of water, nobody will be inclined to contest that you get a greatly increased efficiency, and I believe that it is not at all impossible, if they are as widely separated as in these models, to drive them at the ordinary speed attained with horizontal engines, without gearing and with excellent effect.